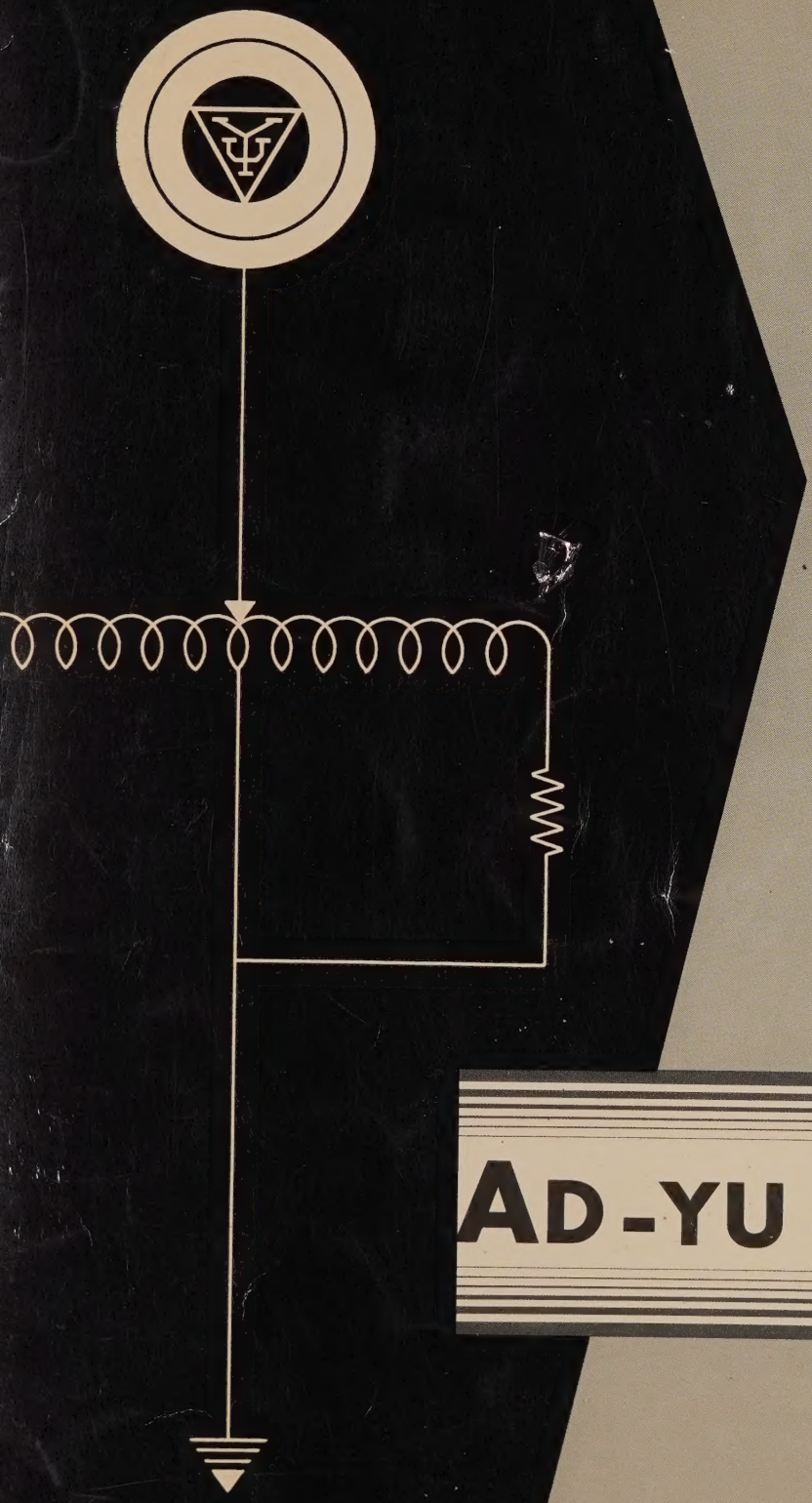

Electronic

INSTRUMENTS

Type 202 PHASE METERS

DELAY LINES

INSTRUMENT
CENTER

AD-YU ELECTRONICS LAB., INC.

249-259 TERHUNE AVE.,
PASSAIC, N. J., U.S.A.
PHONE: GR 2-5622
CABLE: ADYU PASSAIC

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VECTORLYZER

TYPE 202

New

FEATURES

ACCURACY: 0.02° or 2%.

RESOLUTION: 0.005° deviations can be read.

FULL SCALE SENSITIVITY: 1° or 0.01 Volt RMS.

FREQUENCY RANGE: 20 cps to 40 kc; up to 500 megacycles with relaxing accuracy.

AD-YU
Formerly
ADVANCE

NEW PASSAIC LABORATORY

ELECTRONICS LAB., INC.

249 Terhune Ave., Passaic, N. J.

DESCRIPTION

This instrument makes possible for the first time a number of measurements which were formerly impossible, or at best very difficult to accomplish by other means. For example, it can be used to measure very small phase angles (such as a fraction of 1°) with a maximum error of less than 0.02° or 2% when using the range of 1° full scale. The operating principle of this instrument is based on measuring vector difference of two input voltages, which permits unusual speed and accuracy for measuring vector relations of alternating voltages.

Type 202 is essentially a combination of the following elements: Two step attenuators, two continuously adjustable attenuators, a wide-band phase inverter, an amplitude selector, a degenerative vector difference amplifier, a bridge rectifier, a balanced cathode follower, a high frequency probe, and a regulated power supply. These elements, except the regulated power supply, are arranged as shown in the block diagram of Fig. 1. The high frequency probe consists of a differential rectifier of which the natural resonant frequency is made very high (above 1000 mc). The differential rectifier is a special type of peak rectifier circuit which is capable of producing a direct current potential at its output terminals proportional to the vector difference between the two voltages applied to its input terminals.

Let E_1 and E_2 be the two input signals and θ be their phase difference. When their amplitudes are made equal to $|E'_1|$ and $|E'_2|$ respectively by adjusting the built-in attenuators, the meter reading E_o may be expressed in terms of phase angle θ as

$$(1)\quad E_o = E'_2 - E'_1 = |E'_1|(\cos\theta + j\sin\theta - 1) \text{ When } |E'_1| = |E'_2|$$

Then we have

$$(2)\qquad |E_o| = |E'_1|\quad (\cos\theta - 1)^2 + \sin^2\theta = 2|E'_1|\sin(\theta/2)$$

By arranging terms

$$(3)\qquad |E'_1| / |E_o| = 1/[2(\sin\theta/2)]$$

Thus the output meter may be calibrated to indicate phase angle in degrees between two voltages. For instance, when $|E'_1|$ is made equal to the half-scale reading during adjustment of attenuators, the meter will read 60 degrees at its center, 0 degree at zero and 180 degrees at full scale. By substituting $\theta = 2°$ in Equation (3), we may find $|E'_1| / |E_o| = 28.65$. Therefore, by applying signal amplitude $|E'_1|$ equals 28.65 times the voltage amplitude for full scale deflection, the meter will read 2° at full scale.

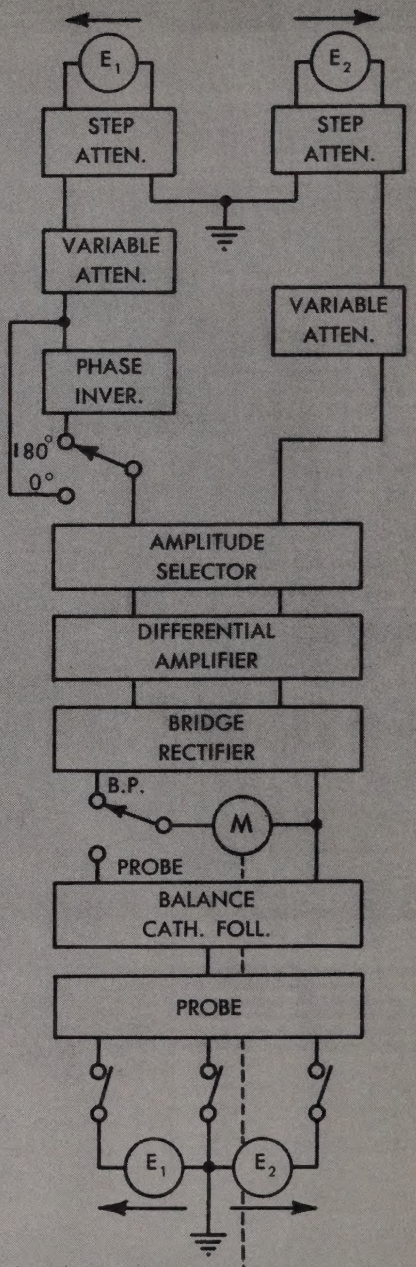


Fig. 1—Simplified block diagram of Type 202 Vectorlyzer.

USES

MEASURING VERY SMALL PHASE ANGLE FROM 15 CPS TO 50 KC. The instrument provides full scale deflection of 1°, 2°, 4°, 10° and 20°. The scale of these phase ranges is 4½ inches long and has 100 divisions total, top scale in Fig. 2. Phase deflection as small as 0.005° (18 seconds) will produce movement of half division on the 1° range.

MEASURING PHASE ERROR BETWEEN AN UNKNOWN COMPONENT AND A STANDARD COMPONENT. Deviation as small as 0.005° can be detected by using the 1° phase range of the instrument. Phase error over a wide frequency range can easily be measured simply by changing the signal frequency, since the instrument is a wide-band device.

MEASURING VOLTAGE ACROSS TWO POINTS WHICH ARE BOTH ABOVE GROUND POTENTIAL. Vector difference of two alternating voltages can be read directly on the panel meter, since the instrument is basically a vector difference voltmeter. A 180° phase inverter is provided in one channel in order to convert the instrument into a vector sum voltmeter.

MEASURING VECTOR RELATIONS UP TO 500 MEGACYCLES. An r.f. probe is provided for reading vector difference of two voltages up to 500 mc directly on the panel meter. When the amplitudes of two input signals and their vector difference are known, phase angle as well as vector sum can be easily determined.

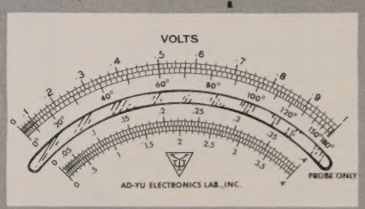
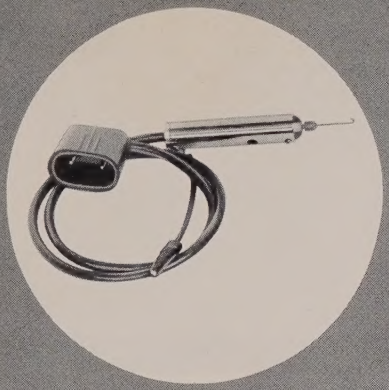


Fig. 2—Mirror scale, 4½" long; 0–1° full scale deflections.

ACCESSORIES



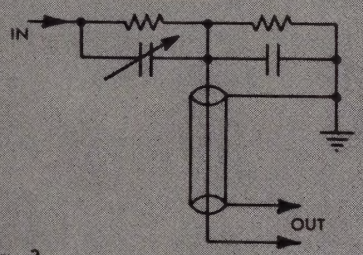
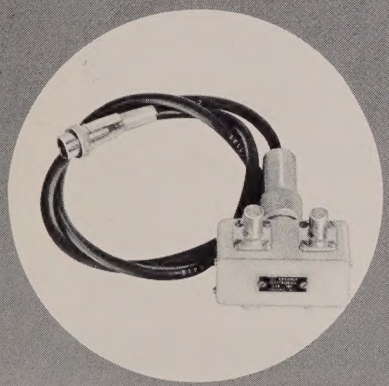


Fig. 3 —
Two attenuator probes with 40 db attenuation supplied with instrument.



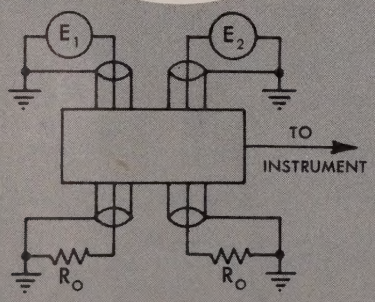


Fig. 4 —
Coaxial probe useful up to 500 mc supplied with instrument.

For distorted input signal, a matched pair of Ad-Yu Type A103 bandpass filters can be supplied on request. For increasing signal sensitivity, a matched pair of Type A102 plug-in preamplifiers with 40 db gain can be supplied on request.

SPECIFICATIONS

20 CPS TO 40 KC INPUT TO BINDING POST

PHASE ANGLE RANGE:
0-1, 0-2, 0-4, 0-10, 0-20 and 0-180 degrees. A panel switch is provided for inserting 180-degree phase shift to convert above ranges into 180-181, 180-182, 180-184, 180-190, 180-200, and 180-360 degrees respectively.

ACCURACY:
Voltage Measurement—The accuracy of scale tracking (reading on any point of the scale) is within ±1.5% of full scale up to 40 kc, ±2% up to 100 kc. The full scale reading can be set exactly equal to the voltage standard with negligible error by adjusting the continuously variable attenuator.

Phase Measurement—The maximum error is less than ±0.02° or ±2% of the full scale of the phase range used for frequency up to 20 kc with ratio of the input signals equal to 1, 3, 10, 30 and 100; for other ratios of input signals, the maximum error is less than ±0.06° or ±2% up to 20 kc. Error increases slowly up to ±0.03° at 50 kc for signal ratios of 1, 3, 10, 30 and 100; for other ratios, the maximum error is less than ±0.8° or ±2% up to 40 kc.

FREQUENCY RANGE: (SEE ACCURACY)

INPUT IMPEDANCE:
20 uuf shunted by 1 megohm at binding post terminals; 5 uuf shunted by 1 megohm at the input terminal of the 40 db attenuator probe.

VOLTAGE RANGE:
The maximum voltage sensitivity for full scale deflection is 0.007 volt rms or better. With variable attenuator at calibrated position (marked ".01v rms"), direct reading on panel meter in volts rms full scale is 0.01 at "Ratio 1" position. Step attenuator with ratios of 3, 10, 30 and 100 gives 4 additional ranges, 0.03, 0.1, 0.3 and 1 volt full scale. With plug-in probe attenuator (100 to 1 attenuation), it gives 5 additional ranges, 1, 3, 10, 30 and 100 volts full scale.

MINIMUM SIGNAL AMPLITUDE FOR PHASE MEASUREMENT:
For phase range of 1° full scale, the minimum amplitude for both input signals is required to be 0.4v rms; for 2° full scale, 0.2v rms is required; 4°-0.1v rms; 10°-0.04v rms; 20°-0.02v rms; 180°-0.004v rms.

MAXIMUM SIGNAL AMPLITUDE FOR PHASE MEASUREMENT:
Signal amplitude up to 100 volts can be applied to the instrument for phase measurement by means of the continuously adjustable attenuators, step attenuators, and plug-in probe attenuators having 100 to 1 ratio supplied with the instrument.

STABILITY OF PHASE MEASUREMENT:
The stability of phase reading depends primarily on the stability of input signal amplitudes. Since the instrument is based on measuring vector difference of two input signals, phase reading will be stable when both input signals have constant amplitudes, otherwise will vary proportionately with signal amplitudes.

EXPANDED SCALE:
For accurate measurement of phase angle between 0 to 360°, an expanded scale may be provided on request at a moderate extra charge. For example, scales from 90° to 91°(89°), 90° to 92°(88°), 90° to 94°(86°) with accuracy of ±0.02° may be obtained for approximately 3 to 1 frequency range with frequency center specified on order.

ATTENUATORS:
Two identical continuously adjustable attenuators are provided with one in each channel. The attenuation ratio is approximately 4 to 1. Two identical step attenuators are also provided, one in each channel, having steps of 1, 3, 10, 30 and 100. The accuracy of attenuation can be made almost exact by adjusting the continuously variable attenuator; otherwise, the accuracy of attenuation is ±3%. In addition, two plug-in-probe attenuators having 100 to 1 ratios ±3% are provided for extending the attenuation range of the step attenuator.

WAVEFORM DISTORTION:
Harmonics and noise will affect the accuracy of phase measurement unless they are identical for both signals. Otherwise, a matched pair of Ad-Yu A103 bandpass filters should be used, with one in each channel. For voltage measurement, the instrument measures the rms value of both the fundamental component as well as harmonics and noise.

40 KC TO 500 MC — INPUT TO PROBE

ACCURACY:
±3% below 100 mc, increasing slowly up to ±5% at 500 mc for both voltage and phase measurements.

FREQUENCY RANGE:
100 kc to 500 megacycles.

INPUT IMPEDANCE:
2.5 uuf shunted by 100,000 ohms; coaxial arrangement with BNC connectors for matching low impedance cable and terminating resistors, or jack input with 2.5 uuf and 100k can be supplied on request.

VOLTAGE RANGE:
0.4, 2 and 4 volts rms full scale.

MINIMUM VOLTAGE FOR PHASE MEASUREMENT:
0.2V for 0-180°; higher voltage required for more sensitive range.

PHASE MEASUREMENT:
Direct reading in degree only with equal input signals; with triangle method calculator, or curves otherwise.

INPUT POWER:
60 watts at 115 volts rms ±10% 50/60 cycles (230 volts available on request).

STABILITY:
Meter indication changes 0.1% or less for 10% variation of line voltage.

PHYSICAL SIZE:
Panel—19"x10½" with mounting slots for all standard racks. Chassis—17"x8¼"x4". Cabinet 12"x10"x20½"; 16 gauge steel light gray wrinkle finish, round corners.

PRICE:
$588.00 F.O.B. Passaic, N. J.
Delivery normally 1-2 weeks.

March 1961 Made in U.S.A.

SUGGESTED APPLICATIONS

PHASE ERROR AS SMALL AS 0.005° of an unknown transformer, resolver, angular pickup, or transducer with respect to a reference standard can be detected. Type 202 is set for 1° full scale.

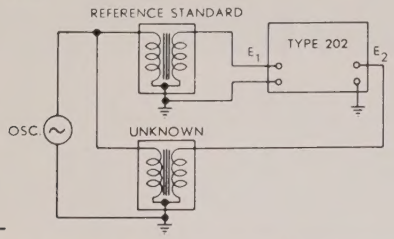


Fig. 5 —

PHASE DEVIATION FROM 90° can be measured down to 0.05° with Type 202, two equal capacitors—C_1, C_2, and two equal resistors—R_1, R_2. Select the value of R_1 equal to $1/wc$, and use the 1° (or 2°) range of Type 202. If E_2 is exactly 90° lag in respect to E_1, the phase reading on Type 202 in the following arrangement will be exactly zero. For 90° lead, interchange C_1 with R_1, C_2 with R_2.

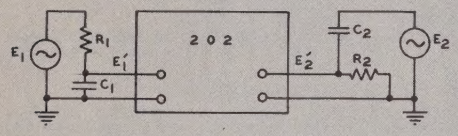


Fig. 6 —

PHASE NULL DOWN TO 0.005° OF A DIFFERENTIAL TRANSFORMER OR TRANSDUCER can be achieved by using the 1° (or 2°) phase range of Type 202. In case the transducer under test produces a large amount of harmonics and hum, a matched pair of Ad-Yu Type A103 bandpass filters should be used at both E_1 and E_2 input.

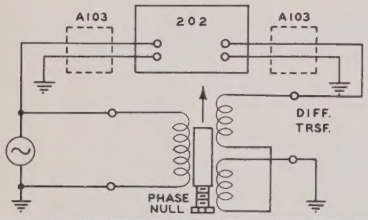


Fig. 7 —

PHASE MEASUREMENT WITH ACCURACY OF 0.2° can be performed for an unknown network with Type 202 as null detector and Ad-Yu Type 208 as phase generator. The unknown phase is read on the dials of Type 208.

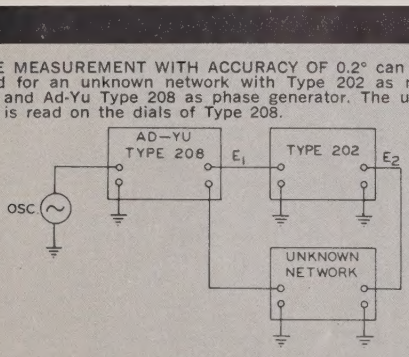


Fig. 8 —

QUADRATURE AND INPHASE COMPONENTS OF RESOLVER OUTPUT can be measured by: (a) Set the E_2 continuously variable attenuator at "0.01V" and E_2 step attenuator for correct voltage range. (b) Adjust the attenuators in E_1 channel until meter deflection becomes minimum. Now the meter reads the quadrature components of the resolver output directly in volts rms. Next, set E_2 attenuator at ∞ position and remove E_2 input. Now the meter reads the inphase components of the resolver output.

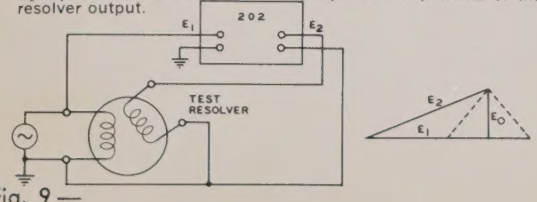


Fig. 9 —

PHASE SHIFT OF HIGH GAIN AMPLIFIERS can be measured accurately by using a voltage divider for stepping down the input signal amplitude for the amplifier under test, while sufficient signal amplitude can be obtained to operate the small phase ranges of Type 202. R_1 and R_2 should be kept under 1k in order not to create phase shift between E_1 and E'_1 by the input capacitance of the amplifier. Phase shift of transformers or attenuators having high amplitude ratio can be measured by interchanging leads E_1 and E'_1.

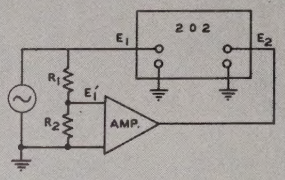


Fig. 10 —

TRANSMISSION CHARACTERISTICS OF COAXIAL CABLE, especially twin lead coaxial cable, can be compared accurately by means of measuring the vector difference of the output voltage. Apply a single input signal of sufficient amplitude to the input of the two cables under test. Vector difference as small as 0.01V can easily be detected up to 500 mc.

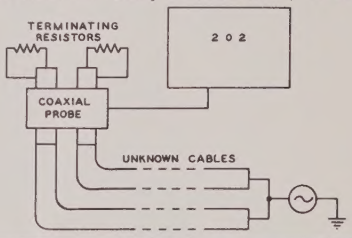


Fig. 11 —

POWER FACTOR AS LOW AS 0.001 of an inductor, a winding of a synchro, resolver, or transformer can be measured on the 1° range of Type 202. $R_1 = R_2$ and C approximately equal to $1/(w^2L)$. Vary the signal frequency slowly until the phase reading becomes minimum, which is the loss factor angle of inductor L.

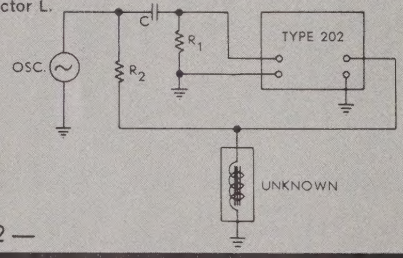


Fig. 12 —

PRECISION PHASE MEASUREMENT WITH 0.2° ACCURACY between E_1 and E_2 can be performed by using the phase range below 10° on Type 202. If the phase to be measured is larger than 10°, use a pure resistance and a low-loss capacitor for reducing the phase difference between E_1 and E_2.

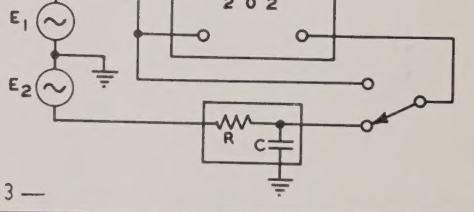


Fig. 13 —

EXPANDED SCALE 90° to 91° (89°), 90° to 92° (88°), with error less than 0.02° can be provided for more than three to one frequency range on request. Such modification is very desirable for measurement of 90° shifting networks in single side-band radio telephone or servo control systems.

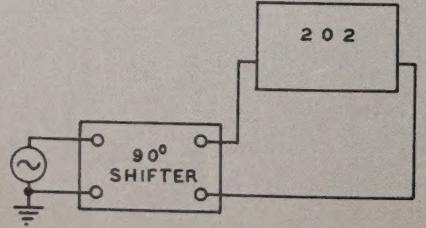


Fig. 14 —

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INSTRUMENT CENTER

TYPE 202 VECTORLYZER

CIRCUIT DESCRIPTION:

Type 202 Vectorlyzer is essentially a combination of the following elements: Two step attenuators, two continuously adjustable attenuators, a wide-band phase inverter, a degenerative vector difference amplifier, a bridge rectifier, a balanced cathode follower, a high frequency probe, and a regulated power supply. These elements, except the regulated power supply, are arranged as shown in the block diagram of Fig. 1.

The differential amplifier has two stages, see Fig. 2. The "AMPLITUDE SELECTOR" control consists of two cathode followers and one 2-pole, 6-position switch. The switch is connected at the cathode circuits of the cathode followers for changing the amount of voltages applied to the differential amplifier. The high frequency probe consists of a differential rectifier, which is a special type of peak rectifier capable of producing a direct current potential at its output terminals proportional to the vector difference between the two voltages applied to its input terminals, see Fig. 3.

COMPLETE CIRCUIT DIAGRAM:

A complete schematic diagram of Type 202 Vectorlyzer, except its regulated power supply, is shown in Fig. 4. The second half of V_2 is used as a phase inverter. V_1 and V_3 are connected as cathode followers for both variable attenuators. The first halves of V_2 and V_4 are used in the "AMPLITUDE SELECTOR" control for measuring small phase angle. D_1 to D_4 are employed as bridge rectifier. Twin-triode V_7 is arranged as a balanced cathode follower and is used to excite the panel output meter. Fig. 5 shows the regulated power supply for this instrument.

DESCRIPTION OF FRONT PANEL CONTROLS AND TERMINALS:

1. "POWER ON", toggle switch, S_9 in Fig. 5 - Used to turn on or to turn off the power.
2. "E_1 IN", binding post, provides for connection of an input signal to E_1 channel.
3. "E_1 ATTENUATION RATIO, E_1 IN/Meter Reading", 2-pole, 6-position switch, S_1 in Fig. 4, select the attenuation ratio for input signal at "E_1 IN" binding post to meter reading.
4. "E_1 ATTENUATION INC.", 3k - 300 ohm coaxial potentiometers, R_1 and R_{1a} in Fig. 4. - This acts as a continuous adjustment of the signal amplitude in E_1 channel with 3k pot as coarse control and 300 ohm pot as fine control.
5. "E_1 SHIFT", 0-180°, 2-pole, 2-position switch, S_4 in Fig. 4. - Introduce a phase shift of 180° at the 180° position by inserting a phase inverter stage to V_2, introducing no phase shift at 0° position in which V_2 is by-passed.
6. "AMPLITUDE SELECTOR", 2-pole, 6-position switch, S_2 in Fig. 4. - This control is used for measuring small phase angles.

First set to the desired full scale phase sensitivity position, adjust amplitudes of E_1 (or E_2) to full scale, then adjust E_2 (or E_1) for minimum meter deflection. Phase angle can now be read directly on the first scale at "READ" position. This control should always be set at "READ" position for all other measurements, otherwise the sensitivity of the instrument is low.

7. "METER ZERO", 100k potentiometer, R_3 in Fig. 4. - This control is used to zero the output meter only when the probe is being used. No electrical zeroing is needed for binding post input.
8. "E_2 ATTENUATION INC.", 3k - 300 ohm coaxial potentiometers, R_2 and R_{2a} in Fig. 4. This serves as continuous adjustment of the signal amplitude in E_2 channel with 3k pot as coarse adjustment, 300 ohm pot as fine adjustment.
9. "BINDING POST, METER OFF, PROBE", 2-pole, 3-position switch, S_6 in Fig. 4. - Serves (1) to connect the panel meter to the output of the bridge rectifier D_1 - D_4 when the input signals are applied to binding post, (2) to short the meter terminal in order not to damage the panel meter when the input signals are being connected or disconnected, (3) to connect the panel meter to the output of the balanced cathode follower when input signals are applied to probe.
10. "E_2 ATTENUATION RATIO, E_2 IN/Meter Reading", 2-pole, 6-position switch, S_3 in Fig. 4. Select the attenuation ratio for input signal at "E_2 IN" binding post to meter reading.
11. "E_2 IN", binding post, - provides for connection of an input signal to E_2 channel.
12. "PROBE RANGE", 1-pole, 3-position switch, S_5 in Fig. 4. - Select sensitivity of the panel meter when the probe is used for 0.4, 2 and 4 volts rms full scale.
13. "ATTENUATOR PROBE" - Two attenuator probes having 40 db attenuation and input capacitance of 4 uuf are supplied with the unit in order to extend all voltage ranges by 100 times.

WARNING:

1. Ground: In order to avoid undesirable pickup, the instrument must always be grounded together with all input sources. One ground point for one device or one signal source is recommended for avoiding pickup loop.
2. "BINDING POST, METER OFF, PROBE", should be set at "METER OFF" when not in use to prevent excessive damage of panel meters.

PREPARING THE INSTRUMENT FOR OPERATION:

1. Set "BINDING POST, METER OFF, PROBE" to "METER OFF" and both "ATTENUATION RATIO" switches to their respective " ∞ " ground positions.
2. Plug line cord into 115-volt (230 volts available on special order), 50-60 cycle supply and turn power on.
3. Select attenuation ratio suitable for both input signals.

4. For meter zero, use mechanical control-screw on the meter with S_6 at "METER OFF" when binding posts are used, or the "METER ZERO" control when the probe is used.
5. Set "AMPLITUDE SELECTOR" switch to "READ" position for all measurements except when measuring small phase angles.

MEASURING VECTOR DIFFERENCE OF TWO UNKNOWN VOLTAGES:

Since the two input terminals of a differential amplifier or rectifier can be connected to points which are both above a.c. ground potential, the vectorlyzer becomes a simple and convenient device for determining the vector difference of two voltages. For operation at high frequencies, 100 kc to 500 mc, connect the two unknown voltages to the two connectors at one side of the probe, and terminate their characteristic impedance at the other side, see Fig. 10. The output meter will read directly the vector difference of the two unknown voltages. For operation at low frequencies, 20 cps to 100 kc, the procedure is as follows:

1. Set "BINDING POST, METER OFF, PROBE" switch to "BINDING POST".
2. Set both "E_1 ATTENUATION RATIO" and "E_2 ATTENUATION RATIO" switches to a position having equal attenuation and its full scale reading higher than the amplitude of the larger signal.
3. Set "AMPLITUDE SELECTOR" control to "READ" position, set "E_1 ATTENUATION INC." and "E_2 ATTENUATION INC." at "0.01" position.
4. Apply both signals simultaneously and take meter reading. The answer is the product of the reading on the panel meter multiplied by the ratio indicated on the dial of "E_1 ATTENUATION RATIO".

USING THE VECTORLYZER AS A SIMPLE VOLTMETER:

For frequencies above 100 kc, it is recommended to apply the signal to one connector of the probe and ground the other connector of the same side. For frequencies below 100 kc, it is recommended to turn "E_2 ATTENUATION RATIO" switch to ground, set "E_1 ATTENUATION INC." at "0.01", "E_1 ATTENUATION RATIO" at a position which provides sufficient attenuation in order not to overload the panel meter, and apply input signal only to "E_1 INPUT" binding post. The amplitude of input signal equals the ratio at "E_1 ATTENUATION RATIO" times the meter reading.

OPERATING PRINCIPLES OF MEASURING PHASE ANGLE WITH 0-180° SCALE, 20 CPS TO 100 KC:

In Fig. 8, E_1 and E_2 are two unknown voltages, and the arrows indicate their polarities. If the amplitudes of E_1 and E_2 are made equal by adjusting the attenuators, the meter reading E_o may be expressed in terms of phase angle θ as

(1) $E_o = E_2' - E_1' = |E_1| (\cos\theta + j\sin\theta - 1)$, then we have

(2) $|E_o| = |E_1| \sqrt{(\cos\theta - 1)^2 + \sin^2\theta} = 2\,|E_1| \sin(\theta/2)$

Thus the output meter may be calibrated to indicate phase angle in degrees between two voltages.

For instance, when E_1 is made equal to the half-scale reading (0.5v) during adjustment of attenuators, the meter will read 60° at its center, 0° at zero and 180° at full scale.

In case that the phase angle between two voltages under consideration is nearly equal to 180°, the accuracy of reading can be greatly increased by introducing a phase shift of 180° in E_1 channel. After inserting 180°, a second scale starting with 180° at its normal zero position is then established.

PROCEDURE FOR USING 0-180° FULL SCALE:

1. Turn "AMPLITUDE SELECTOR" switch to "READ" position.
2. Apply E_1 to "E_1 IN" binding post, set "E_1 ATTENUATION RATIO" to a position of which the full scale sensitivity is slightly larger than the amplitude of E_1, and set "E_2 ATTENUATION RATIO" to ground. Then adjust "E_1 ATTENUATION INC." control until the pointer of the meter reaches the mid-point of the voltage scale, namely the mark "0.5" at the top scale.
3. Set "E_1 ATTENUATION RATIO" to ground, and set "E_2 ATTENUATION RATIO" to a position of which the full scale sensitivity is slightly larger than the amplitude of E_1, apply E_2 to "E_2 IN" binding post, then adjust "E_2 ATTENUATION INC." control until the pointer of the meter again reaches the mid-point of the voltage scale.
4. Apply both E_1 and E_2 simultaneously, set both "ATTENUATION RATIO" switches for E_1 and E_2 to the positions used in (2) and (3) respectively, and read the phase angle directly on the "0-180°" scale. Add 180° to the meter reading when the selector for "E_1 SHIFT 0-180°" is set at "180°" position.

OPERATING PRINCIPLE FOR MEASURING SMALL PHASE ANGLE, 20 CPS TO 100 KC:

Referring to Eq. (2), when the phase angle θ decreases, the magnitude of E_o may be held constant if the amplitudes of the input voltages increase accordingly. This in turn keeps the indication on the output meter unchanged, since it is energized by the magnitude of E_o. To be specific, let us assume that it is desired to increase the full scale phase sensitivity of the instrument from 180° to 2°. In order to achieve this goal, readjust both attenuators so that the magnitudes of E_1 and E_2 will be equal to 28.75 times the full scale reading instead of half scale. The value of 28.75 is obtained by substituting $\theta = 2°$ in the following equation.

(3) $|E_1| / |E_o| = 1/[2(\sin \theta/2)] = 28.75$

Therefore, by applying signal amplitude E_1 equals 28.75 times the voltage amplitude for a full scale deflection, the meter will read 2° at full scale.

Since the sine function of a small phase angle is approximately proportional to the magnitude of the angle, we can use the voltage scale (the top scale of the meter) to read phase angle directly with an error less than ¼% from 0° to 4°, 3/4% at 10°. By using equation (3), we may write:

(4) $\theta = 2 \sin^{-1} (|E_o| / 2|E_1|) = 57.5 (|E_o| / |E_1|)$, when θ is small.

This equation indicates that the meter will have full scale sensitivity equal to 1^{o} when E_1 equals to 57.5 times its full scale voltage sensitivity; 2^{o} when E_1 equals to 28.75 times; 4^{o} when E_1 equals to 14.375 times; 10^{o} when E_1 equals to 5.75 times, etc. This method is possible only when both input voltages have sufficient amplitude. The minimum signal amplitude required for full scale deflection of 1^{o} is 0.46v; 2^{o} - 0.23v; 4^{o} - 0.115v; 10^{o} - 0.046v; 20^{o} - 0.023v; 180^{o} - 0.004v.

PROCEDURE FOR USING 0-1^{o} FULL SCALE:

1. Turn "AMPLITUDE SELECTOR" control to 1^{o} position at which the attenuation is 57.5 to 1. Minimum input signal is 0.46v.
2. Set "E_1 ATTENUATION RATIO" to a position at which both the coarse and fine controls of "E_1 ATTENUATION INC." can be set for full scale deflection in (3).
3. Apply E_1 to "E_1 IN" binding post, and connect "E_2 ATTENUATION RATIO" to ground, then adjust "E_1 ATTENUATION INC." control until the pointer of the meter reaches full scale, namely the mark "1" on the top (voltage) scale, see Note 1 below.
4. Apply both E_1 and E_2 simultaneously to the respective binding posts. Set "BINDING POST, METER OFF, PROBE" switch to "METER OFF" to avoid overloading of the panel meter when turning other controls. Turn "BINDING POST, METER OFF, PROBE" switch to "BINDING POST", then adjust both "E_2 ATTENUATION RATIO" and "E_2 ATTENUATION INC." controls until meter reading becomes minimum when "AMPLITUDE SELECTOR" control at 1^{o}, 4^{o}, 20^{o} and finally at "READ" position. Read the phase angle directly on the top (voltage) scale.

Note 1: The difference of attenuation between both "E_1 ATTENUATION INC." and "E_2 ATTENUATION INC." should be set no more than 50% apart in order to avoid excessive error. In other words, they should be set to yield about equal attenuation for both coarse and fine controls of E_1 and E_2 channels. In addition, if "E_1 ATTENUATION INC." control has to be set for more attenuation than its mid-range, then "E_1 ATTENUATION RATIO" should be switched to the next higher position. Similar caution should be taken in E_2 channel.

PROCEDURE FOR USING 0-2^{o} FULL SCALE:

All procedures are identical to those just described, except set "AMPLITUDE SELECTOR" switch to 2^{o} position at which the attenuation is 28.75 to 1, and set "E_1 ATTENUATION RATIO" and "E_2 ATTENUATION RATIO" switches to a position of which full scale deflection can be obtained with the input signal divided by 28.75. Minimum signal amplitude is 0.23v.

PROCEDURES FOR USING 0-4^{o}, 0-10^{o}, and 0-20^{o} FULL SCALE:

All procedures mentioned above can be used with the exception that the setting of the positions of "E_1 ATTENUATION RATIO" and "E_2 ATTENUATION RATIO" has to be different because the attenuation is different at different positions of the "AMPLITUDE SELECTOR" control:

The attenuation is 1/57.5 for 1^{o}, 1/28.75 for 2^{o}, 1/14.325 for 4^{o}, 1/5.75 for 10^{o}, and 1/2.857 for 20^{o}.

PROCEDURES FOR USING $0\text{-}60^{o}$ FULL SCALE:

1. Identical to those given in the procedure of "$0\text{-}180^{o}$".
2. Similar to (2) in the procedure of "$0\text{-}180^{o}$", except adjusting the "E_1 ATTENUATION INC." until the pointer of the meter reaches full scale, namely the mark "1" on the top scale.
3. Similar to (3) in the procedure of "$0\text{-}180^{o}$", except adjusting the "E_2 ATTENUATION INC." until the pointer of the meter reaches full scale, instead of half scale.
4. Apply both "E_1 and E_2" simultaneously, take meter reading as E_o and compute the phase angle by using the following equation:
   (5) $\theta = 2 \sin^{-1} (|E_o| /2)$, where E_o is the reading on the top scale of the meter in step No. 4.

In general, for full scale of A degrees, set both E_1 and E_2 equal to .5/(sin A/2) volts and determine the phase angle in degrees by using the following equation:

(6) $\theta = 2 \sin^{-1} (|E_o| /2|E_1|)$, where E_o is the voltage reading obtained in step No. 4.

Add 180^{o} to the meter reading when selector for "E_1 SHIFT, 0^{o} - 180^{o}" is set at "180^{o}".

MEASURING PHASE ANGLE ABOVE 100 KC THROUGH PROBE:

Fig. 9 shows the basic circuit of the instrument when it is operated at very high frequencies. Coaxial probe is supplied with the instrument. Fig. 10 shows a circuit diagram of a coaxial probe, connectors A and B for signal sources E_1 and E_2 of which their terminating resistors or loads are connected respectively at connectors C and D. Duotriode T_7 is arranged as a balanced cathode follower, Symbol M represents the output meter. Potentiometer R_3 is used for zero adjustment. E_1 and E_2 are the two unknown voltages. Meter M reads $E_1 - E_2$ when both E_1 and E_2 are applied to the probe.

PROCEDURES FOR MEASURING PHASE ANGLE ABOVE 100 KC:

The simplest method for phase measurement at high frequencies is by using the knowledge of simple geometry. The procedure is as follows:

1. Turn "BINDING POST, METER OFF, PROBE" switch to "PROBE". Zero set the meter with both probe terminals shorted to ground. In Fig. 10, apply E_1 to A and terminate E_1 at C apply E_2 at B and terminate E_2 at D. Then read E_2-E_1 on panel meter.
2. Remove E_2 and terminate E_2 source with the same terminating resistor as at D.
3. Ground B of Fig. 10, read E_1.
4. Remove E_1 from A and terminate E_1 source with same terminating resistor as at B. Then ground A of Fig. 10, read E_2.
5. Draw a triangle with E_1, E_2, and E_1-E_2 as its three sides, as shown in Fig. 11.
6. Determine the phase angle between any two voltages by using the triangle of Fig. 11 with a protractor.

MEASURING SMALL PHASE ANGLE ABOVE 100 KC:

Phase angles below 20^{o} can be measured accurately if the amplitude for one of the input voltages can be continuously adjustable without changing its phase. The procedure is as follows:

1. Connect the input voltage with fixed amplitude to one input terminal, and ground the other input terminal. Record the meter reading as E_1.
2. Apply both input signals to the two input terminals of the probe for measuring the vector difference, E_2-E_1. Adjust the amplitude of E_2 until the meter reading becomes minimum. Turn the "RANGE" switch to more sensitive position if needed.
3. The phase angle between E_1 and E_2 is equal to the meter reading divided by a factor $0.0174E_1$. The operating principle can be explained with the use of the following equation.

   (7) $|E_o| = |E_2| - |E_1| = 2|E_1| \sin(\theta/2)$ for $|E_2| = |E_1|$

   then

   (8) $\theta = 2 \sin^{-1}(|E_o|/2|E_1|) = |E_o| / (0.0174|E_1|)$, when θ is small.

MEASURING VECTOR SUM OF TWO VOLTAGES:

For 20 cps to 100 kc, the operating procedure is very similar to measuring vector difference of two voltages except set "E_1 SHIFT 0^{o}-180^{o}" to "180^{o}" position, then the vector difference amplifier will become vector sum amplifier, and the meter will read the vector sum of two input voltages.

MEASURING COMPLEX COMPONENTS OF AN UNKNOWN VOLTAGE:

The vectorlyzer is a simple and convenient device for direct indication of the imaginary and real components of an unknown voltage in terms of a reference voltage. In Fig. 8, E_1 and E_2 are assumed to be the reference and unknown voltages respectively. Adjust the attenuator in E_1 channel until the deflection of the output meter reaches a minimum. To represent this condition, a vector diagram is drawn in Fig. 12 for E_1, E_2 and E_o. Symbol E_o denotes the reading of the output meter. Since these three vectors form a right triangle, the diagram indicates: (1) E_o equals the imaginary component of E_2, and (2) E_1 equals the real component of E_2. Thus the meter reads directly the imaginary component after the attenuator in E_1 channel has been adjusted for minimum meter reading. Then remove E_2, ground E_2 IN binding post, the meter now indicates directly the real component of E_2.

In case that the phase angle between the unknown voltage and the reference voltage is greater than 90 degrees, but less than 270 degrees, the preceding method of measuring complex components still remains useful when E_1 is shifted 180 degrees with respect to E_2 by means of inserting the phase inverter. Without inserting the phase inverter it would be impossible to reduce the indication of the output meter to a value less than the absolute amplitude of E_2.

MEASURING UNKNOWN IMPEDANCE:

The magnitude and phase angle of an unknown impedance may be measured by using the arrangement shown in Fig. 13. Z_x is the unknown impedance, R is a pure resistor with its value approximately equal to the magnitude of Z_x, and E is an oscillator whose output is set within the scale of E_1 and E_2 range. The procedure is as follows:

1. Measure the phase angle between the applied voltage E and the unknown impedance Z_x by means of the method described above.
2. Measure the amplitude of the applied voltage E.
3. Measure the amplitude of the potential drop across unknown impedance, E_{Zx}
4. Draw a triangle with phase angle θ measured in (1) and the voltages measured in (2) and (3). This triangle is shown in Fig. 14. Now a perpendicular can be drawn from the point A toward E_R. The phase angle ϕ can be measured on the triangle as the angle of the unknown impedance. The magnitude of the unknown impedance $Z_x = R(E_{Zx}/E_R)$.

MEASURING RATIO OF TWO VOLTAGES:

Since Type 202 Vectorlyzer consists of two step attenuators and two continuously variable attenuators having adjustable attenuation from 1 up to more than 300, the ratio of two different voltages, $|E_2| / |E_1|$, can be conveniently measured. The procedure is as follows:

1. Set "AMPLITUDE SELECTOR" switch to "READ" position and set "E_1 ATTENUATION RATIO" to a position slightly larger than the amplitude of E_1. Set "E_2 ATTENUATION RATIO" to ground.
2. Apply E_1 to "E_1 IN" binding post, then adjust "E_1 ATTENUATION INC." control until the meter reading equals "0.1" on the top (voltage) scale.
3. Remove E_1 and connect E_2 to "E_1 IN" binding post. Now the meter indicates directly the ratio of E_2 to E_1. If the indication is too small to read accurately, turn "E_1 ATTENUATION RATIO" to lower attenuation. In this case, the reading should be multiplied by the reduction in attenuation ratio. If the indication is over scale, turn "E_1 ATTENUATION RATIO" to higher attenuation and divide the meter reading by the corresponding increase in attenuation.

NOTES ON MAINTENANCE:

When anyone of the diodes D_1 to D_4 is replaced, the calibration of the instrument should be checked by connecting an accurately known a.c. source (or an accurate voltage divider) to input binding post at audio frequency. If diode D_5 is replaced, the instrument should be checked by measuring an accurately known a.c. source having frequency above 80 kc with the high frequency probe. The facilities available in this instrument for calibration adjustment are shown as follows:

COMPONENT	LOCATION
R_5	Rear panel of chassis 0.01 V Binding Post
R_6	Rear panel of chassis 0.4 V Probe
R_7	Rear panel of chassis 2 V Probe
R_8	Rear panel of chassis 4 V Probe

Calibration Error with Signal Applied to Panel Binding Posts: 0.01 volt range with "ATTENUATION RATIO" at 1, - Error at full scale can be eliminated by adjusting potentiometer R_5. If replacement of D_1-D_4 does not eliminate the error, this may be due to the curvature of operating of D_1-D_4 does not conform with the scale. Then the method for remedy is as follows: (1) Correct reading at full scale, readings become smaller at mid-scale and at lower half scale, such as 0.0045 for 0.005V input, 0.0025 for 0.003V input. Give more signal to the differential amplifier by setting the pointer of "ATTENUATION INC." knob at "0.01" volt mark for less attenuation. Then adjust R_5 again for correct meter reading. This would move the operation of D_1-D_4 to a region with less curvature. If the pointer already reaches the position of zero attenuation, increase the values of the resistors at the plate of both 6AU6's for higher amplification or replace both 6AU6. (2) Correct reading at full scale. Readings become larger at mid-scale and at lower half scale, such as reading of 0.0055 for 0.005V input, 0.0032 for 0.003V input. Give less signal to the differential amplifier by setting the pointer of "ATTENUATION INC." knob at "0.01" volt mark for more attenuation. Then adjust R_5 again for correct meter reading. This would move the operation of D_1-D4 to a region with more curvature. This can also be accomplished by reducing the gain of both 6AU6's by means of decreasing the values of their resistors at the plates.

Higher ranges, "ATTENUATION RATIO" at 3, 10, 30 or 100 - For high frequencies, the trimmers used in that particular range of the input attenuator are out of adjustment. For low frequencies, the vernier "ATTENUATION INC." pot. should have its knob set at different position or the resistors used in that particular range of the input attenuator should be replaced.

Calibration Error with Signal Applied to Probe: Errors at full-scale, adjust R_6 for 0.4 volt, R_7 for 2 volt, R_8 for 4 volts. Errors at mid-scale or below mid-scale, replace diode D_5. Error at high frequencies, replaced diode D_5 or other components in the probe.

Meter "DEAD": This may be caused by power supply failure, defective tube, open meter, diode D_1 to D_5 defective, attenuator switch defective.

Motorboating: This may be caused by defective electrolytic condenser, failure of the regulation of B^+ voltage, or excessive leakage of any one of the coupling capacitors in the differential amplifier.

Unstable: This may be caused by leakage from one or more of the coupling capacitors in the cathode follower and/or in the differential amplifier stages. Also, this may be caused by poor regulation from the power supply or fluctuation of the regulating tube OB2. Coupling condenser leakage can be detected by using high input resistance vacuum tube voltmeter to measure the voltage across the grid lead resistor, which should be zero with good condenser.

Phase Reading Negative: This may be caused by: (1) Signals contain too much hum; (2) Diodes D_1, D_2, D_3, D_4 and D_5 are very non-linear, particularly with probe and the ratio of two signals being very high; (3) The phase angle to be measured is zero or very nearly zero, and the amplitude adjustment is incorrect.

Unstable at Zero Reading: Binding post input - This may be due to defective coupling condenser in the bridge rectifier, or defective diodes D_1 to D_4. Input binding posts are not grounded, and have excessive pick-up. Probe - This may be caused by the connecting cable being shorted to ground, or the coupling condenser in the probe has excessive leakage. Also, this may be caused by defective crystal diode D_5 or duo-triode T_6.

Voltage Reading Negative: Probe - This may be caused by the crystal diode inside of the probe which has been connected incorrectly. This may be easily remedied by reversing the polarity of the diode connection. Binding Post - This may be caused by the lead of the panel meter which has been reversed, or one of the diodes D_1 to D_4 is defective.

Voltage Reading at 0^o Does Not Agree with that at 180^o Position of E_1 Channel: R_4 located at top of chassis should be adjusted to give identical voltage reading at either position.

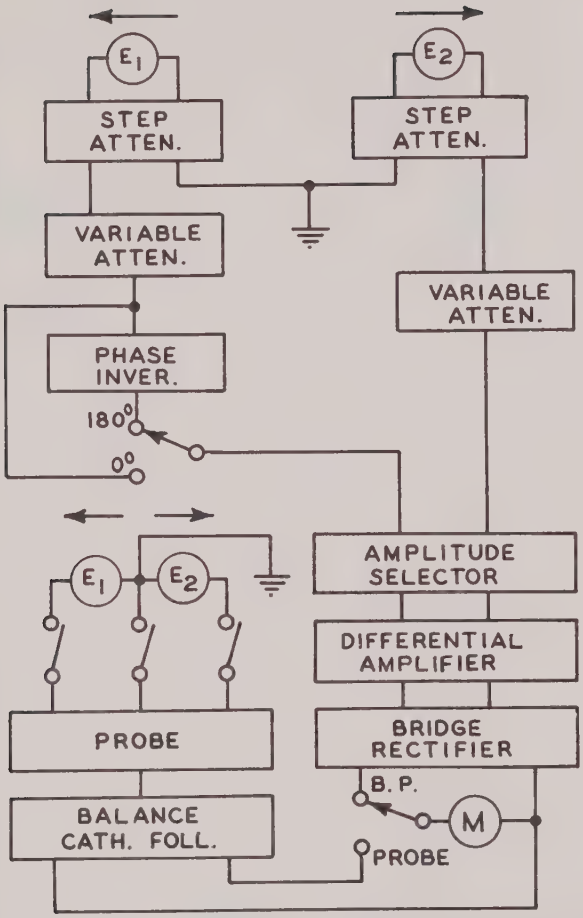
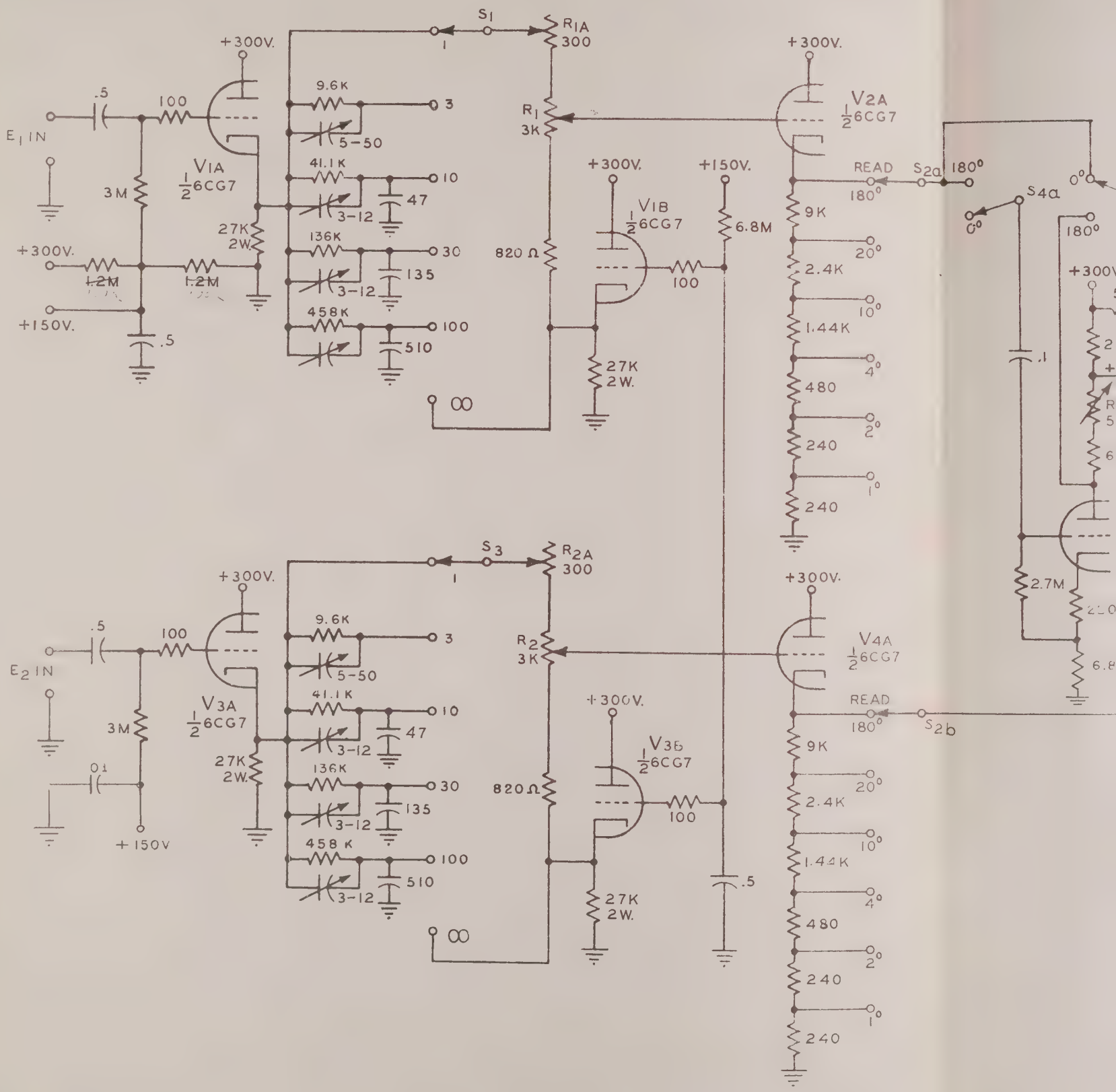


FIG. 1 – BLOCK DIAGRAM OF TYPE 202
E_1 AND E_2 ARE INPUT SIGNALS


S1
R1A
300
+300V.
.5
100
E1 IN
V1A
1/2 6CG7
3M
27K
2W.
+300V.
1.2M
1.2M
+150V.
.5
9.6K
5-50
3
41.1K
3-12
47
10
136K
3-12
135
30
458K
3-12
510
100
R1
3K
820 Ω
∞
+300V.
V1B
1/2 6CG7
+150V.
6.8M
100
27K
2W.
+300V.
V2A
1/2 6CG7
READ
180°
S2a
180°
0°
9K
20°
2.4K
10°
1.44K
4°
480
2°
240
1°
240
S4a
0°
180°
.1
2.7M
S3
R2A
300
+300V.
.5
100
E2 IN
V3A
1/2 6CG7
3M
.01
+150V
27K
2W.
9.6K
5-50
3
41.1K
3-12
47
10
136K
3-12
135
30
458K
3-12
510
100
R2
3K
820 Ω
∞
+300V.
V3B
1/2 6CG7
100
27K
2W.
.5
+300V.
V4A
1/2 6CG7
READ
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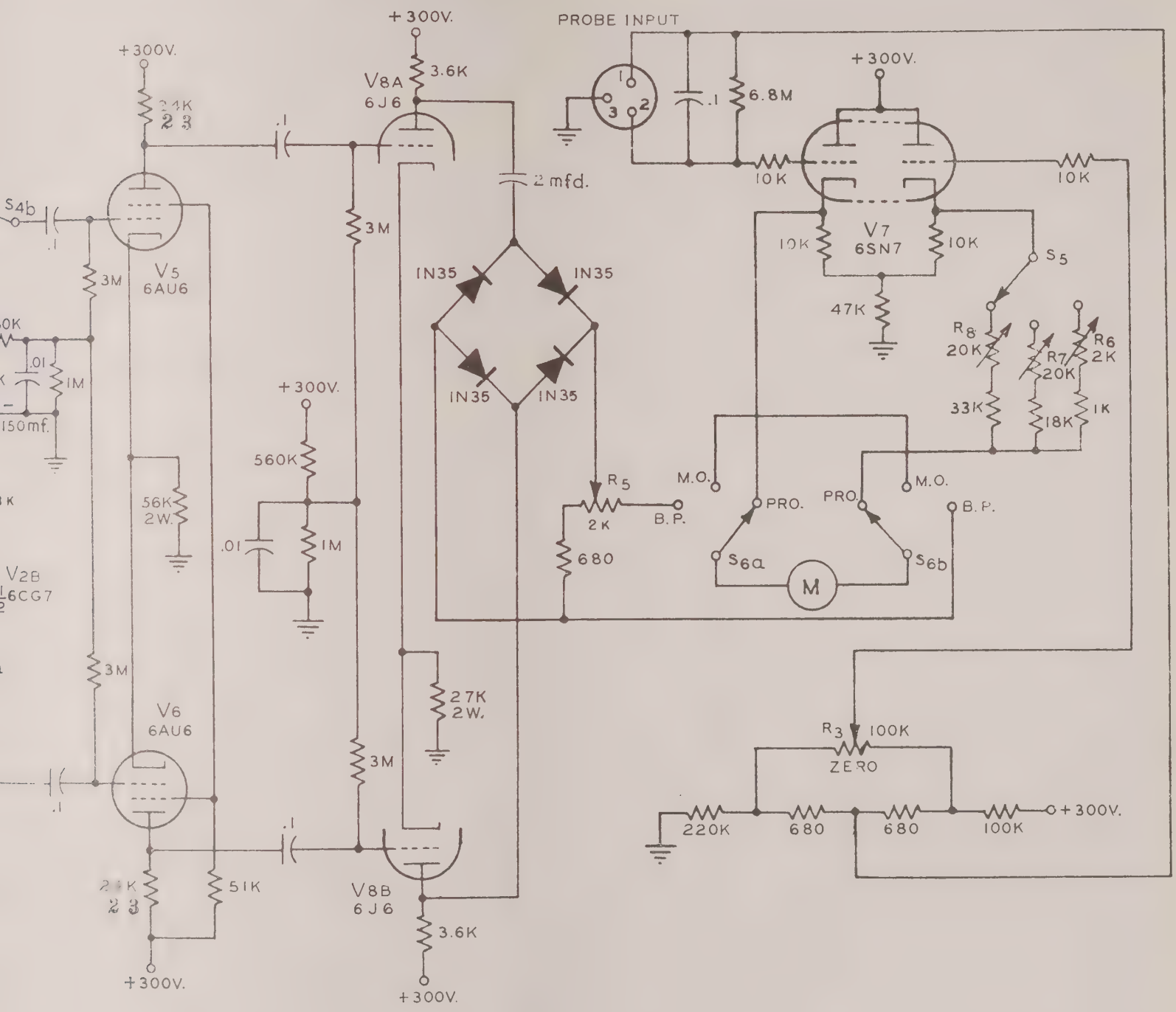
S2b
9K
20°
2.4K
10°
1.44K
4°
480
2°
240
1°
240



TYPE	202 VECTORLYZER
DATE:	NOV. 1960
DRAWN BY:	B. Y.

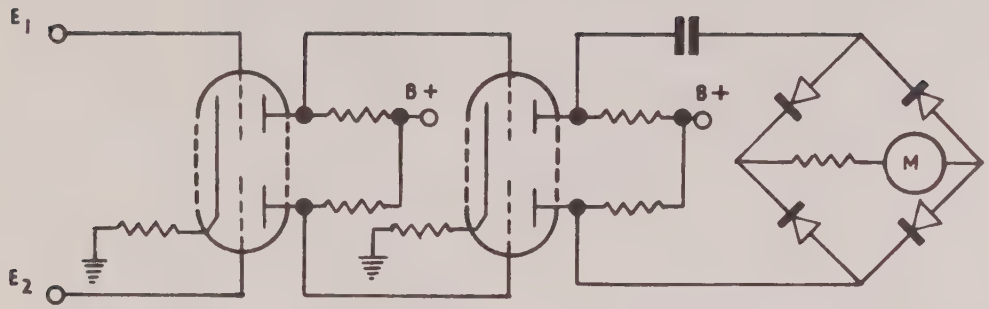


FIG. 2 — SIMPLIFIED DIAGRAM OF DEGENERATIVE DIFFERENTIAL AMPLIFIER AND BRIDGE RECTIFIER.

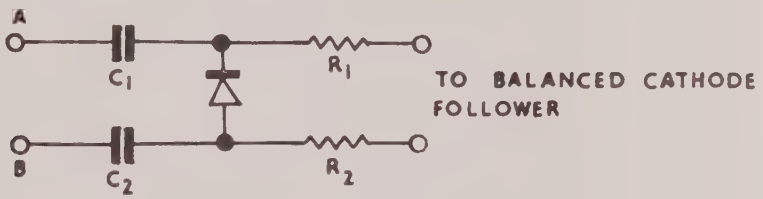


FIG. 3. — BASIC DIFFERENTIAL RECTIFIER CIRCUIT.

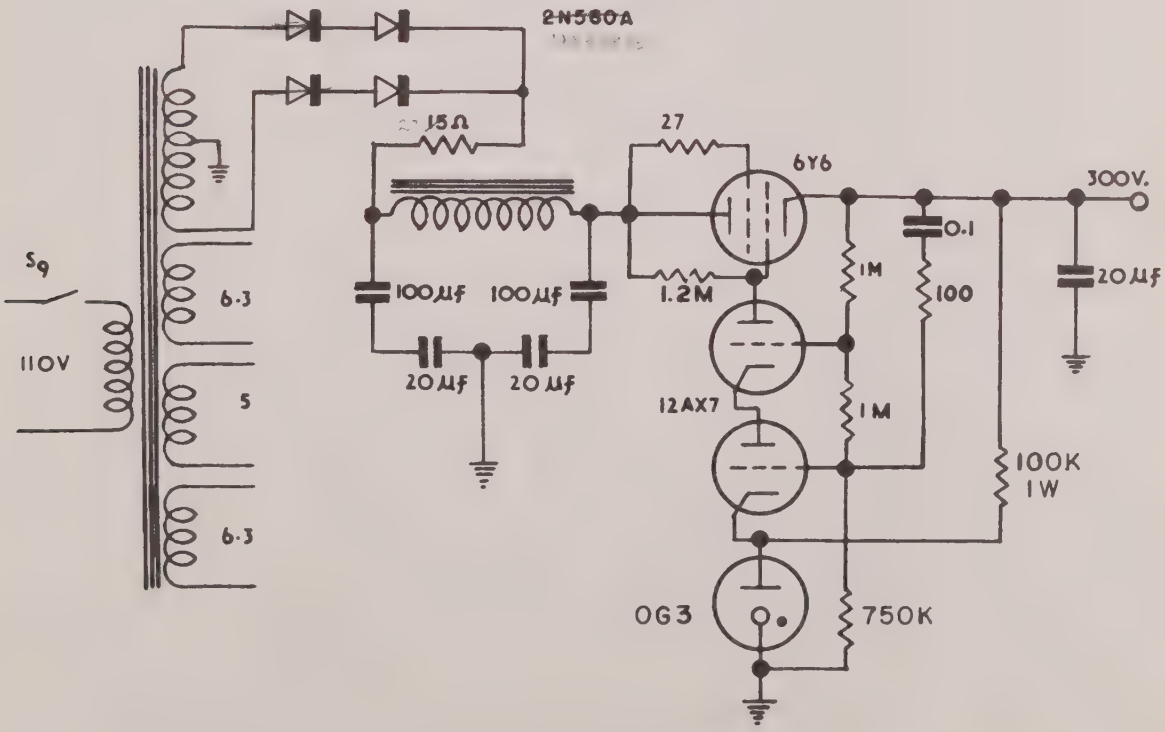


FIG. 5 — REGULATED POWER SUPPLY.

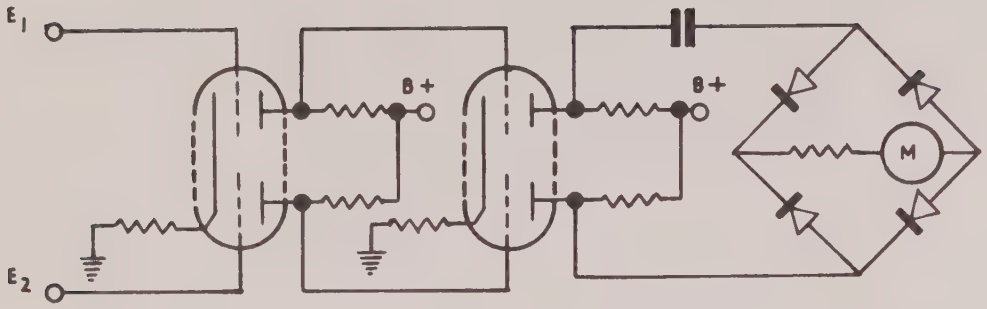


FIG. 2 — SIMPLIFIED DIAGRAM OF DEGENERATIVE DIFFERENTIAL AMPLIFIER AND BRIDGE RECTIFIER.

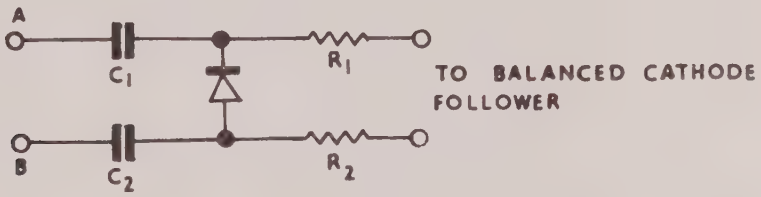


FIG. 3. — BASIC DIFFERENTIAL RECTIFIER CIRCUIT.

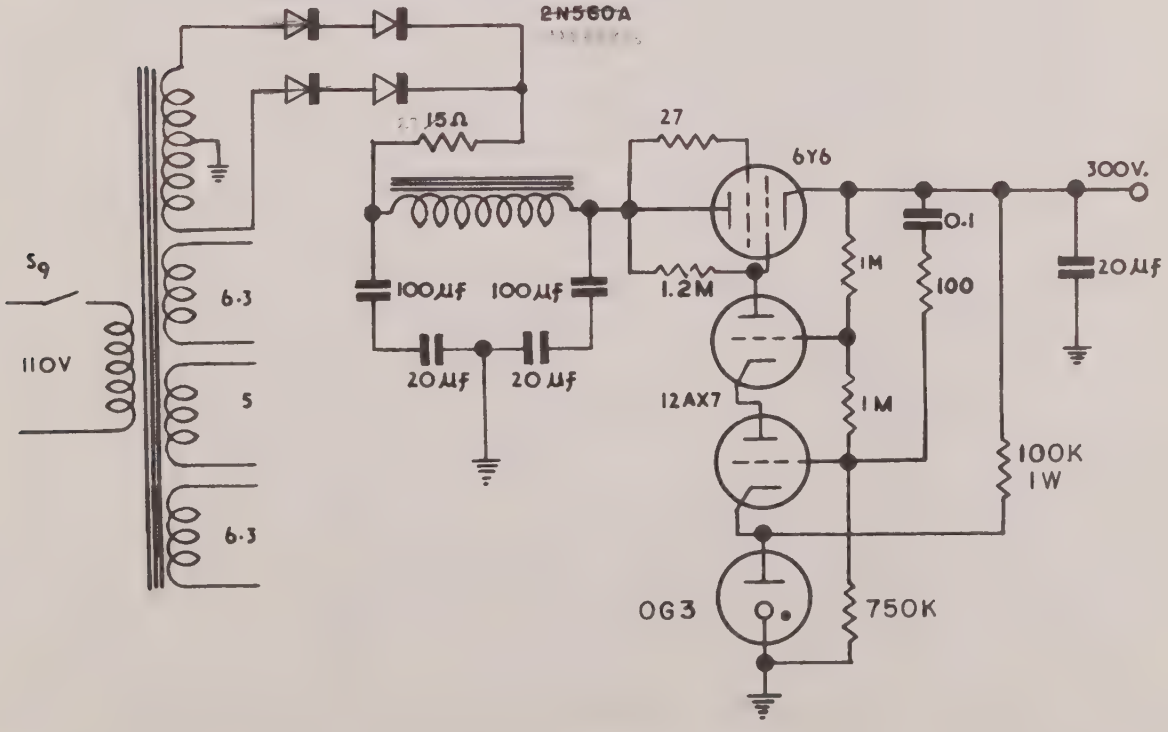


FIG. 5 — REGULATED POWER SUPPLY.

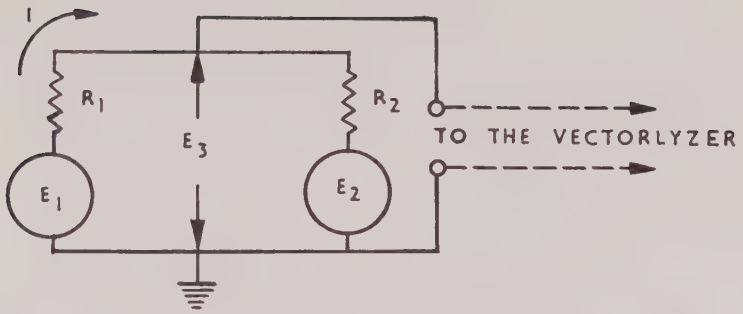


FIG. 6 — BASIC CIRCUIT FOR MEASURING VECTOR SUM OF TWO VOLTAGES.

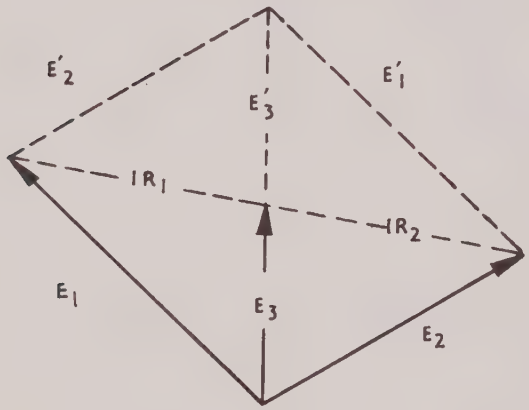


FIG. 7 — VECTOR DIAGRAM IN CONNECTION WITH THE CIRCUIT OF FIG. 6.

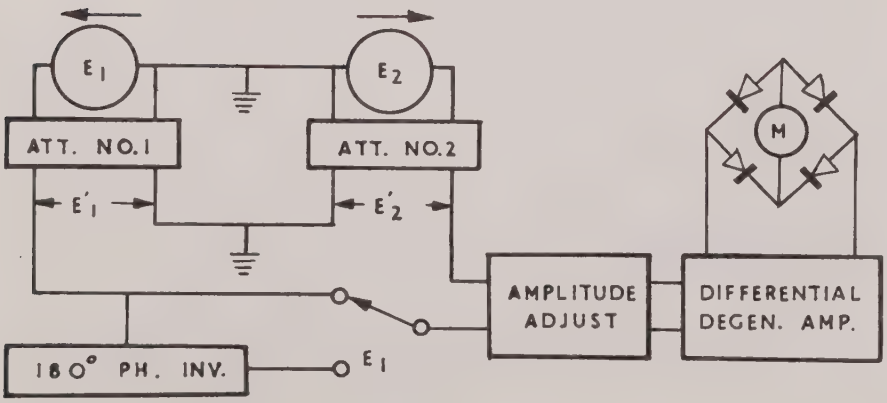


FIG. 8 — BASIC CIRCUIT FOR MEASURING PHASE ANGLE.

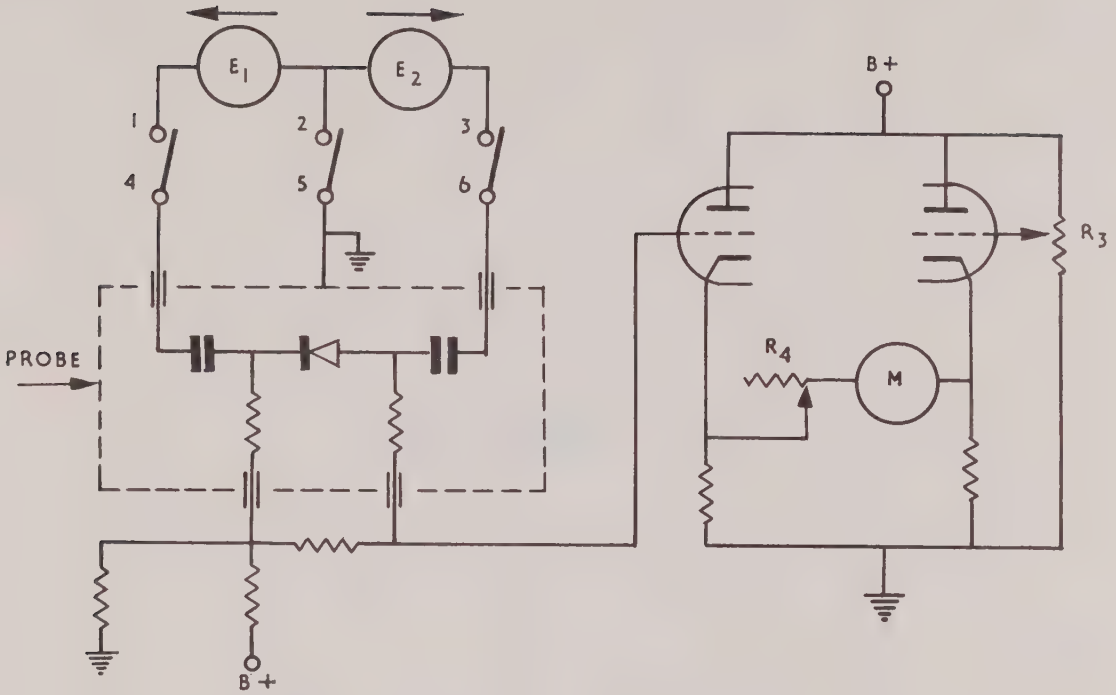


FIG. 9 — BASIC CIRCUIT OF THE VECTORLYZER FOR OPERATION AT HIGH FREQUENCIES.

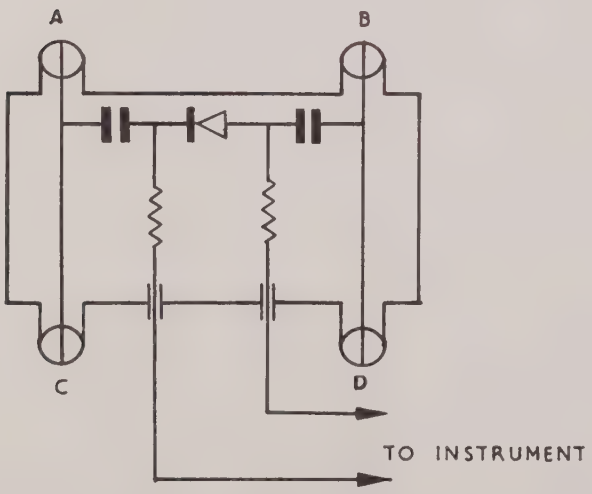


FIG. 10 — CIRCUIT DIAGRAM OF COAXIAL PROBE. A AND B FOR SIGNAL SOURCES; C AND D, RESPECTIVELY, FOR THEIR TERMINATING RESISTORS OR LOADS.

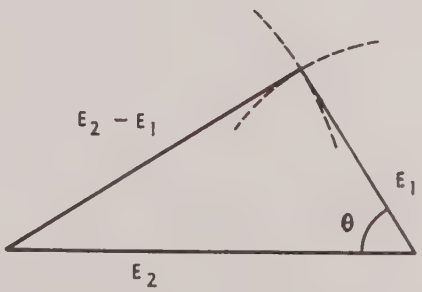


FIG. 11 — A TRIANGLE USED FOR DETERMINING THE PHASE ANGLE BETWEEN E_1 AND E_2.

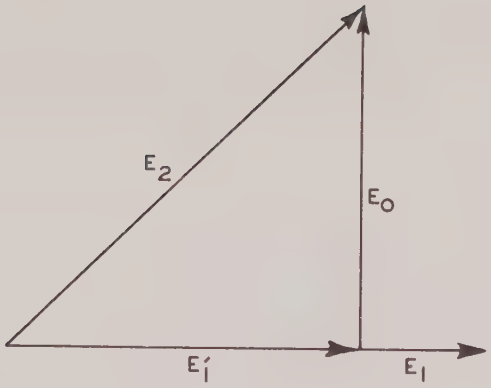


FIG. 12 — VECTOR DIAGRAM FOR MEASURING COMPLEX COMPONENTS OF AN UNKNOWN VOLTAGE

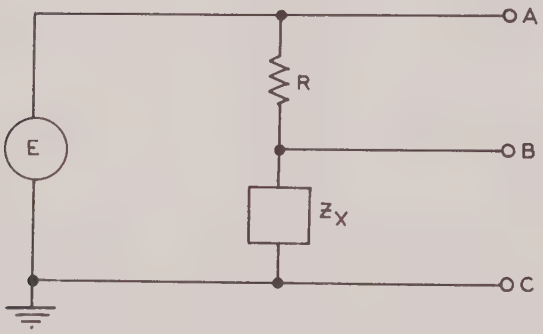


FIG. 13 — CIRCUIT FOR MEASURING UNKNOWN IMPEDANCE

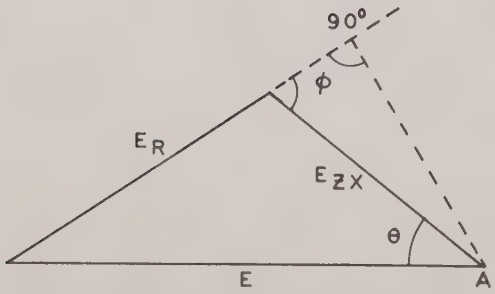
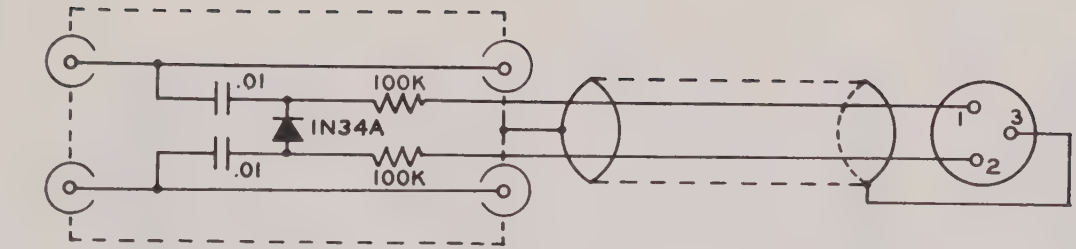
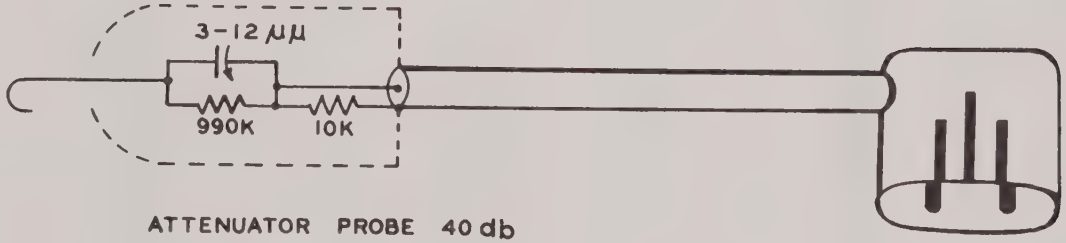


FIG. 14 — TRIANGLE EXPRESSING THE VECTOR RELATION OF THE ARRANGEMENT IN FIG. 13.



V.H.F. PROBE .1 TO 500MC



ATTENUATOR PROBE 40 db

FIG. 15. ACCESSORY PROBES FOR TYPE 202

PRECISION PHASE METERS

0.00001 cps to 1500 mc. Direct reading in degrees or in microseconds. Accuracy ±0.05° or ±1%. Rental service available.

PRECISION PHASE METERS TYPE 405 405H 405L

FEATURES • Direct reading in degrees . . . Measures a small fraction of 1° . . . 0.1 volt sensitivity . . . ¼° relative accuracy . . . 1 cps to 500 kc . . . Meter reading independent of input signal amplitudes . . . Equal accuracy for symmetrical waveforms of any shape . . . No adjustment before obtaining reading . . . Useful for automatic plotting of phase response curves, servo testing, and correlation between two random signals.

Specifications

FREQUENCY RESPONSE: Type 405—8 cps to 100 kc; Type 405H—8 cps to 500 kc; Type 405L—1 cps to 40 kc.

PHASE RANGE: Direct reading in degrees with 8 ranges: 0-12° (0-120° for 405H), 0-36°, 0-90°, 0-180°; panel switch provided for 180° phase shift in order to convert these to 180-192° (180-300° for 405H), 180-216° 180-270°, 180-360°.

ACCURACY: ¼° relative, ±1° or ±2% of full scale absolute.

INPUT VOLTAGE: Type 405 and 405L—0.1 volt to 70 volts rms; Type 405H—0.3 volt to 30 volts rms.

INPUT SIGNAL RATIO: Any value between 1 to 700 for 405 and 405L; 1 to 130 volts for 405H.

CHARACTERISTICS OF OUTPUT SIGNALS: Output voltage referring to B+ is zero for 0°, increases linearly to —14 volts for 180° in Type 405 and 405L, to —4 volts for Type 405H.

INPUT IMPEDANCE: Type 405 and 405H—3 megohms shunted by 20 uuf on both input channels; Type 405L—6.8 megohms shunted by 20 uuf.

PRICE: Type 405—$598.00; Type 405H—$655.00; Type 405L—$675.00.

VECTORLYZER TYPE 202

FEATURES • Accuray ±0.02° or ±2% . . . 0.01° deviations can be read . . . Full scale sensitivity 1° or 0.01 volt rms below 100 kc . . . Measures phase angle, vector sum or vector difference of two voltages.

Specifications

BELOW 100 KC:

PHASE ANGLE RANGE: 0-1, 0-2, 0-4, 0-10, 0-20 and 0-180 degrees. A panel switch is provided for 180° phase shift for additional 6 ranges.

ACCURACY: ±2% of full scale for voltage measurement; ±0.02° or 2% (whichever is larger) for phase measurement.

INPUT IMPEDANCE: 16 uuf shunted with 1 megohm.

VOLTAGE RANGE: 0.01V, 0.03, 0.1V, 0.3, and 1V full scale; plug-in attenuator having 40 db attenuation gives additional 5 ranges up to 100V full scale.

MINIMUM VOLTAGE FOR PHASE MEASUREMENT: Full scale of 1° requires 0.4V, 2°—0.2V, 4°—0.1V, 10°—0.04V, 20°—0.02V, 180°—0.005V.

ABOVE 100 KC:

INPUT IMPEDANCE: Coaxial arrangement with BNC connectors for 50-ohm impedance. Jack input probe with 100 K input impedance available on request.

ACCURACY: ±3% below 100 mc, increases slowly up to 5% at 500 mc for both voltage and phase measurements.

VOLTAGE RANGE: 0.4, 2 and 4 volts full scale rms.

PRICE: Type 202—$588.00.

PRECISION PHASE DETECTORS TYPE 205A1-A2

FEATURES • Measures phase angle down to 0.02° or time delay down to 8 x 10^{-12} sec. . . . Applicable for continuous sine waves, pulse-modulated or amplitude-modulated sine waves.

Specifications

FREQUENCY RANGE: 100 kc to 15 mc, useful up to 30 mc with relaxing accuracy.

ACCURACY: ±0.05° or ±1% (whichever is larger).

RESOLUTION TIME: Less than 8 x 10^{-12} sec. . . . Smallest phase angle can be detected equals 8 x 10^{-12} x 360 x frequency in cps.

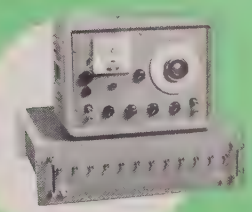
TOTAL TIME DELAY: Type 205A1—0 to 11.1 us; Type 205A2—0 to 1.11 us.

PHASE RANGE: 360° at 100 kc for Type 205A1, 180° at 450 kc for Type 205A2; extension of phase range can be accomplished by exchange of input leads.

INPUT IMPEDANCE: 4 uuf with low capacity probes supplied (20 db attenuation); 12 uuf shunted with 1 megohm direct.

MINIMUM INPUT SIGNAL: Approximately 0.1 volt direct; 1 volt with probe is recommended.

PRICE: Type 205A1—$775.00; Type 205A2—$625.00.



PRECISION PHASE DETECTORS TYPE 205B1-B2-B3

FEATURES • Frequency range 15 mc to over 1500 mc . . . Accuracy ±1% or ±0.05° (whichever is larger) . . . Resolution time actually infinitesimal . . . Single-ended output available for using receiver as external detector . . . Time delay automatically variable (motor-driven, 115V) . . . Visual indication of phase null with oscilloscope . . . Input signal can be CW, pulse modulated or amplitude modulated.

Specifications

READABILITY: Type 205B1 and 205B3—10 uus per division on main scale, 1 uus per division on vernier, 0.1 uus per division with super-vernier. Type 205B2—5 uus per division on main scale, 0.5 uus per division on vernier, 0.05 uus per division on super-vernier. Quarter division can easily be seen on all scales.

TIME DELAY: Continuously adjustable from 0 to 2.8 mus (1.4 mus for 205B2), then variable in steps up to 42.5 mus total.

CHARACTERISTIC IMPEDANCE: 50 ohms nominal for both input and output.

PHASE RANGE: The maximum phase angle is equal to total time delay in us x frequency in mc x 360 in degrees.

FREQUENCY RANGE: Type 205B1—15 mc to 400 mc; Type 205B2 and 205B3—100 mc to 1500 mc.

MINIMUM INPUT SIGNAL: Type 205B1—Approximately 1v with indicator, 1 mv with external receiver. Type 205B2—Approximately 2v with panel indicator, 1 mv with external receiver. Type 205B3—Approximately 1v with oscilloscope, 1 mv with receiver as indicator.

PRICE: Type 205B1—$1742.00; Type 205B2—$2387.00; Type 205B3—$1445.00.

AD-YU
Formerly ADVANCE

ELECTRONICS LAB., INC.

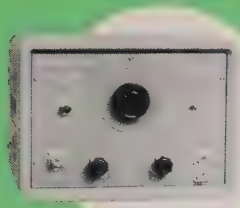
249 Terhune Ave., Passaic, N. J.

PHONE: GRegory 2-5622

CABLE ADDRESS: AD-YU

NEW PASSAIC LABORATORY

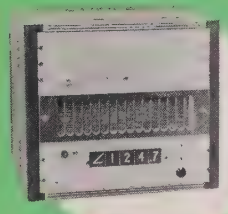
PHASE SHIFTER - GENERATOR TYPE 208 208A



FEATURES • Direct reading in degrees at one frequency from 50 cps to 1000 cps, chart supplied for other frequencies . . . Type 208A has built-in tuning fork oscillator.

Specifications
FREQUENCY RANGE: Direct reading at 400 cps; any other frequency between 50 cps to 1000 cps available on request.
PHASE INDICATION: Direct reading in degrees on 3 dials: 0-270° in 90° steps, 0-90° in 2° steps, 0-2½° continuously variable.
ACCURACY: 0.1° relative, 0.15° absolute.
PHASE SHIFT: Continuous phase adjustment from 0 to 360°.
MAXIMUM OUTPUT SIGNAL: Type 208—15 volts rms; Type 208A—Continuously adjustable up to 5 volts rms.
OUTPUT IMPEDANCE: 300-ohm nominal shunting resistance with 2 uf series capacitor for d.c. blocking.
INPUT IMPEDANCE: (208 only) 1 meg shunted with 25 uuf to ground.
FREQUENCY: (208A only) Stability better than 0.001% per degree centigrade; accuracy within 0.05%.
PRICE: Type 208—$445.00; Type 208A—$645.00.

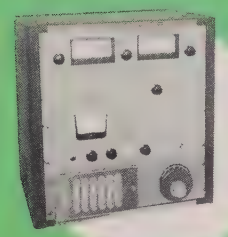
DIGITAL PHASE METER TYPE 524



FEATURES • Phase angle in degrees directly represented in four digits . . . Phase reading independent of the ratio of signal amplitudes . . . No amplitude adjustment, no frequency adjustment for either signal . . . 0.1° resolution.

Specifications
FREQUENCY RESPONSE: 50 cps to 40 kc.
ACCURACY: The relative accuracy is ±0.1°, and the absolute accuracy is ±½°.
PHASE RANGE: 0 to 360.0°, displayed in four digits without range switching.
PHASE INDICATION: Digital readout with numerals having 1" height, in four digits.
INPUT VOLTAGE: 0.3 volt up to 50 volts rms.
INPUT IMPEDANCE: 1 megohm shunted by 30 uuf on both channels.
CHARACTERISTICS OF OUTPUT SIGNALS: Two forms of output signals available: (1) Analog output for recorder —0 for 0° negative, 3.6 volts for 360° with respect to B+ (280 volts). (2) Digital output for operation of data printers, tape punches or card punches.
PRICE: $2465.00.

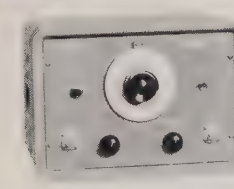
TRANSFER FUNCTION ANALYZER TYPE 308



FEATURES • Direct and simultaneous reading of both in-phase and quadrature components without adjustment or computation. Automatic and continuous plotting of transfer function when used in conjunction with an X-Y recorder.

FREQUENCY RANGE: 0.3 cps to 20 kc.
ACCURACY: ±2% of full scale.
OUTPUT SIGNAL FOR RECORDER: 2 volts for full scale sensitivity at any range; plus polarity for phase lead, negative polarity for phase lag.
HARMONIC RESPONSE: No output resulted from even harmonics, approximately 10 db down for third, 15 db for fifth, and 20 db for seventh harmonic, without filter.
INPUT IMPEDANCE: 1 megohm shunted with 20 mmf.
PRICE: $1,685.00.

SUB-AUDIO TUNED AMPLIFIER
TYPE 301



Selects fundamental components of non-sinusoidal waveform. Frequency response 35 db down for second harmonic, 45 db down for third harmonic, 50 db down for higher harmonics. Center frequency 0.3 to 3000 cps, continuously adjustable.

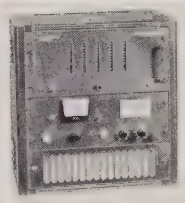
PRICE: $445.00

PANEL-MOUNT PHASE METER
TYPE 410

No electron tube or transistor. No amplitude adjustment, no zeroing. Direct reading in degrees. No drift, no warm-up period required. Input signals 60 to 130 volts rms per phase. Range 0-36°, 0-90° and 0-180°. Accuracy ±2.5% of full scale. Frequency range 30 to 1000 cps.

PRICE: $225.00

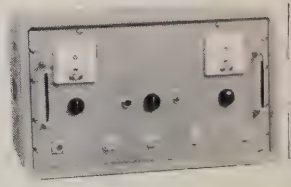
PHASE ANGLE COUNTER
TYPE 1002



Measures instantaneous phase angles directly in degrees in four digits. Revolutionary new gating circuit with interlocking arrangement offers dependable operation. Frequency range 0.005 cps to 500 cps. Accuracy ±0.5°.

PRICE: $948.00

FREQUENCY CONVERTE
TYPE 305



Converts RF signal from 1 mc up to 50 mc to audio frequency for phase measurement with Type 405; requires an external oscillator with frequency about 20 kc above or below the RF signal.

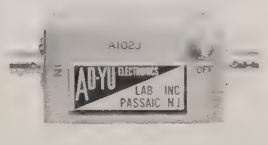
PRICE: $575.00

COAXIAL ATTENUATORS COAXIAL TERMINATIONS
CA-CT SERIES

Extremely low voltage standing wave ratio up to 5000 mc. Accurate and constant attenuation from d.c. up to 5000 mc. Input and output impedance 50 ohms (70 ohms available on request). Attenuation (standard) 1, 2, 3, 4, up to 20 db in 1 db steps. Power rating 1 watt continuous.

PRICE: Attenuators—$38.00
Terminations—$22.00

MINIATURE PRE-AMPLIFIER
TYPE A102 SERIES



Frequency response 1 cps to 1 mc (5 models available). Gain 100, up to 6000. Distortion less than 1%. Self powered, completely transistorized. Noise level less than 3 uv.

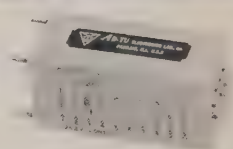
PRICE: $59.00 and up

VARIABLE BANDPASS FILTER
TYPE A103

Select the fundamental component from a distorted signal from 50 cps to 10 kc. Center frequency adjustable over one decade. 40 db attenuation for harmonics.

PRICE: $59.00 & up.

MAGNETIC AMPLIFIER RELAYS
RL-101-2-3-4

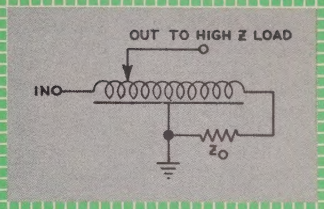


Very high sensitivity: responds to control power of 30 microwatts. Ruggedness: control winding can be continually overloaded 1000 times without damage. Contact rating up to 15 amperes. No transistors, vacuum tubes or delicate mechanisms. No adjustment required throughout the service life.

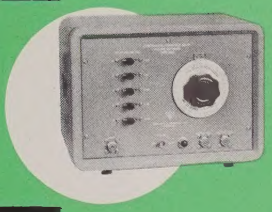
PRICE: $85.00 & up.

CONTINUOUSLY VARIABLE DELAY LINES

STEP VARIABLE AND FIXED



VARIABLE DELAY NETWORK TYPE 2011 2012



FEATURES • The time delay is continuously variable with resolution time less than 8 x 10^{-11} second . . . Consists of input amplifier, one step delay line, one continuously variable delay line and two output cathode followers . . . Passing signals of any waveform . . . No time jitter.

SPECIFICATIONS

ACCURACY OF TIME DELAY: 2% of time delay at any point. Maximum error can be less than 10^{-9} second or 0.3% of time delay at any point (whichever is larger) with correction factors.

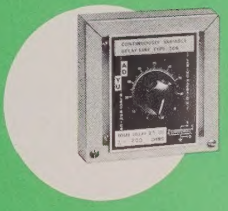
TIME DELAY: Continuously variable from 0 to 11 us for 2011, 16 us for 2012, 22 us for 2013, 32 us for 2014.
RISE TIME: Less than 4% of total delay.

BANDWIDTH: The cutoff frequency is 10 megacycles for the continuously variable delay line; 32/D for the step variable delay, where D is the total time delay.

IMPEDANCE: 20 uuf shunted with 1 megohm direct for input; about 300 ohms for output.

PRICE: $285.00 and up.

CONTINUOUSLY VARIABLE DELAY TYPE 505 - 509



FEATURES • Resolution time less than 8 x 10^{-11} second . . . Load impedance may be made equal to characteristic impedance . . . Rise time less than 10% of the time delay . . . Physical size 1-1/16" x 4-3/16" x 4-3/16", except 1-1/16" x 6-1/32" x 6-1/32" for 507 and 509 series. **PRICE:** $59.00 and up.

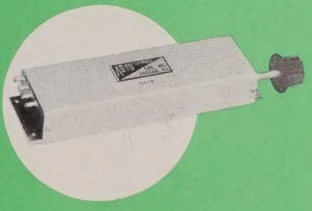
TYPE	DELAY (us)	Zo (ohms)
505	0—0.05	300
505a	0—0.1	150
505b	0—0.12	650
505c	0—0.15	750
505d	0—0.15	185
505e	0—0.08	120

TYPE	DELAY (us)	Zo (ohms)
506	0—0.25	200
506a	0—0.22	180
506b	0—0.28	300
506c	0—0.4	400
506d	0—0.38	300

TYPE	DELAY (us)	Zo (ohms)
507	0—0.8	650
507a	0—0.5	200
507b	0—0.5	385
507c	0—1.2	500
507d	0—0.5	1300

TYPE	DELAY (us)	Zo (ohms)
507e	0—0.55	1300
508	0—0.5	580
508a	0—0.25	1100
508b	0—0.66	600
509	0—1	600

CONTINUOUSLY VARIABLE DELAY TYPE 521 551 - 555



FEATURES • Continuously variable delay down to zero . . . 521 series consists of continuously variable delay line and step variable delay line connected coaxially; 551-3 consists of continuously variable delay line only . . . Rise time less than 4% for 521 series, 10% to 15% for 551-5 series. Temperature coefficient 0.005% per degree C . . . Physical size 4-5/32" x 4-5/32" x 4-1/32" for 521 series, 7¾" x 2⅛" x 1-3/16" for 551-3 series, 7¾" x ¾" x 1½" for 554-5 series.

PRICE: Type 521 Series—$188.00 each; Type 551-555 Series—$89.00 each.

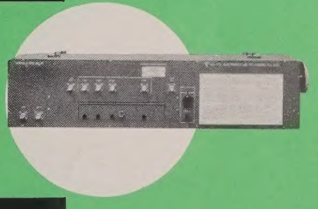
TYPE	DELAY (us)	Zo (ohms)
521a	0—6	500
521b	0—9	750
521c	0—15	1200
521d	0—21	1200
521e	0—30	500
551a	0—1.54	170
551b	0—2.2	110

TYPE	DELAY (us)	Zo (ohms)
551c	0—3.3	66
551d	0—4.4	44
552a	0—2.0	133
552b	0—2.76	141
552c	0—4.4	74
552d	0—6.25	53
553a	0—2.6	173

TYPE	DELAY (us)	Zo (ohms)
553b	0—3.62	120
553c	0—5.5	73
554a	0—0.1	175
554b	0—0.045	205
554c	0—0.055	150
554d	0—0.029	190
554e	0—0.059	100

TYPE	DELAY (us)	Zo (ohms)
554f	0—0.05	80
555a	0—0.05	150
555b	0—0.06	135
555c	0—0.057	205
555d	0—0.065	185
555e	0—0.4	500
555f	0—0.3	650

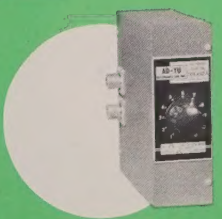
WIDE-BAND TIME DELAY STANDARD TYPE 20A1, - A6 20B1 - B2



FEATURES • Rise time less than 1 micromicrosecond . . . Bandwidth over 1500 megacycles for 20B Series; 200 megacycles for 20A Series with delay up to 1.1 us and 5 megacycles above 1.1 us . . . Readability better than 0.05 uus for 20B2, 0.1 uus for 20B1 on supervernier scale . . . Accuracy better than 1% . . . Input voltage over 500 volts . . . Type 20B1-B2 motordriven, 115V (220V available, $20.00 extra). **PRICE:** $285.00 and up.

TYPE	20B1	20B2	20A1	20A2	20A3	20A4	20A5	20A6
Characteristic Impedance	50 ohms	50 ohms	93 ohms	93 ohms	75 ohms	75 ohms	50 ohms	50 ohms
Resolution Time	infinitesimal	infinitesimal	10 mus	1 mus	1 mus	10 mus	1 mus	10 mus
Total Delay Time	45.3 mus	45.15 mus	11.1 us	1.11 us	1.11 us	11.1 us	1.11 us	11.1 us

STEP VARIABLE DELAY TYPE 602 - 603



FEATURES • Equal input and output impedance with 400 volts maximum input . . . Rise time less than 5% of total time delay . . . Temperature coefficient 0.005% per degree C . . . Operating temperature —55°C to +125°C . . . Cut-off frequency equals 35/D, where D is total time delay . . . 11 different steps with delay per step equal to total delay divided by 11. **PRICE:** $115.00 and up.

TYPE	601	602	602a	602a1	602b	602c	602c1	602d	602d1	602d2	602e	602e1	602e2	602f	602f1	602g	602g1	602g2	602g3
DELAY (us)	2.2	2.75	2.75	5.5	1.1	1.65	2.2	8.25	11	16.5	2.75	1.1	2.2	5.5	11	3.3	2.2	5.5	11
Zo (ohms)	200	200	75	75	75	75	75	75	75	75	50	50	50	50	50	300	300	300	300
DELAY/STEP	0.2	0.25	0.25	0.5	0.1	0.15	0.2	0.75	1	1.5	0.25	0.1	0.2	0.5	1	0.3	0.2	0.5	1
TYPE	602g4	602g5	602h	602h1	602h2	602i	602j	602k	602k1	603	603a	603a1	603a2	603a3	603a4	603b	603b1	702	702a
DELAY (us)	16.5	22	5.5	11	27.5	1.1	5.5	11	16.5	27.5	1.1	2.2	5.5	11	22	5.5	11	10	10
Zo (ohms)	300	150	500	500	500	93	93	93	93	200	100	100	100	100	100	200	200	200	75
DELAY/STEP	1.5	2	0.5	1	2.5	0.1	0.5	1	1.5	2.5	0.1	0.2	0.5	1	2	0.5	1	1	1

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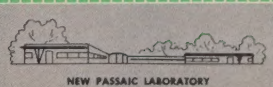

NEW PASSAIC LABORATORY

SPECIALLY DESIGNED TO MEET YOUR REQUIREMENT OR FOR MILITARY USE.

CONTINUOUSLY VARIABLE DELAY TYPE 611

FEATURES • Temperature coefficient less than 0.005% per degree C. No time jitter . . . Fast rise time . . . Accurate dial setting.

Specifications

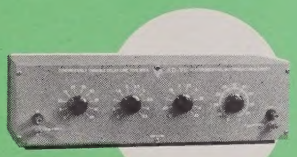
RISE TIME: Less than 4% of the total time delay at any point.
PHYSICAL SIZE: 7¾" x 7¾" x 5½" for 611a series; 19" x 5¼" x 6½" for 611b series.
ATTENUATION: Less than 5 db for all types.

TIME DELAY VARIATION: Continuously variable with incremental time delay less than 8×10^{-11} second for Type 611a's; variable in step of one part per 320 for Type 611b's.
PRICE: $198.00 and up.

TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	OUTPUT Zo
611a1	8 us	8×10^{-11} sec.	600
611a2	16 us	8×10^{-11} sec.	1300
611a3	32 us	8×10^{-11} sec.	750
611b1	16 us	0.05 us	150
611b2	16 us	0.05 us	400

TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	OUTPUT Zo
611b3	8 us	0.025 us	150
611b4	12 us	0.05 us	800
611b5	32 us	0.1 us	400
611b6	64 us	0.2 us	400
611b7	128 us	0.4 us	150

CONTINUOUSLY VARIABLE DELAY TYPE 801



FEATURES • Incremental time delay less than 8×10^{-11} second; total time delay over 200,000 microseconds . . . Attenuation varies from 4 to 12 db . . . 240 sections of LC m-derived networks for 802 Series, 120 Temperature coefficient less than 0.005% per degree C.

Specifications

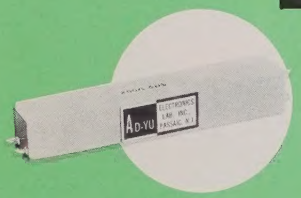
RISE TIME: Maximum rise time is less than 4% for 801a, b, b1 and c; about 2% for all other types.
PANEL SPACE: Front panel is 7" x 19" for 801c, d and e; 5¼" x 19" for all others, with standard rack mount slots.
PRICE: $395.00 and up.

CUTOFF FREQUENCY: Type 801 Series — At maximum delay, the cutoff frequency is 32/D and the 3 db bandwidth is approximately 20/D. Type 802 Series — At maximum delay, the cutoff frequency is 64/D and the 3 db bandwidth is approximately 35/D; where D is the total time delay.
DISTORTION: Less than 3% for all types.

TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	OUTPUT Zo
801a	50 us	8×10^{-11} sec.	1000
801b	100 us	8×10^{-11} sec.	1000
801b1	200 us	8×10^{-11} sec.	500
801c	500 us	8×10^{-11} sec.	No Load
801d	1,000 us	8×10^{-11} sec.	No Load
801e	2,000 us	0.2 us	No Load

TYPE	TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	OUTPUT Zo
801f	802f	5,000 us	0.5 us	No Load
801g	802g	10,000 us	1 us	No Load
801g1	802g1	20,000 us	2 us	No Load
801h	802h	50,000 us	5 us	No Load
801i	802i	100,000 us	10 us	No Load
801j	802j	200,000 us	20 us	No Load

ULTRA-FAST RISE TIME DELAY TYPE 10T 11T



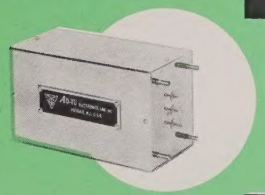
FEATURES • Rise time can be made less than 1% of total delay . . . Phase linear to 2/3 of cutoff frequency . . . Distortion 2% . . . Temperature coefficient less than 0.005% per degree centigrade . . . Attenuation 0.5 db minimum to 1 db maximum for 10T Series; 0.167D for 11TS Series, where D is total delay; 11TL Series less than 4 to 6 db for most types.

Specifications

TOTAL TIME DELAY: 10T—0.27, 0.34, 0.47 up to 15.6 us; 11T—400 up to 224,000 us.
CHARACTERISTIC IMPEDANCE: 10T—150 up to 700 ohms; 11T—475 up to 16,000 ohms.
INPUT VOLTAGE: 10T—500 volts maximum; 11T—100 volts maximum.

NUMBER OF SECTIONS: 10T—20 to 120 sections; 11T—40 to 100 sections.
NUMBER OF TAPS: 10T—2 taps; 11T—2 taps, standard; additional taps on request.
PHYSICAL SIZE: 10T—1" x 1" x 7¼" or larger; 11T—2½" x 2¼" x 5" or larger; size increased proportionally to number of sections.
PRICE: 10T—$49.00 and up; 11T—$145.00 and up.

TAPPED DELAY LINES TYPE 5T 9T

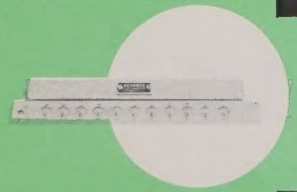


Specifications

NUMBER OF SECTIONS: 5T—100 sections; 9T—20 to 100 sections.
RISE TIME IN PERCENTAGE OF TOTAL DELAY: 5T—3%; 9T—10% for 20 sections to 3.5% for 100 sections.
INPUT VOLTAGE: 500 volts maximum for most types.
TEMPERATURE COEFFICIENT: Less than 0.005% per degree centigrade.
ATTENUATION: 5T—Approximately 3 - 15 db at maximum delay. 9T—1 db for 20 sections up to 4 db for 80 sections.

TOTAL TIME DELAY: 5T—0.5, 1, 1.4 up to 500 us; 9T—4, 5, 6, 7.5 up to 500 us.
CHARACTERISTIC IMPEDANCE: 5T—50, 70, 75 up to 2000 ohms; 9T—320, 500, 620 up to 2500 ohms.
NUMBER OF TAPS: 2 taps; additional taps on request.
PHYSICAL SIZE: 5T—2⅛" x 2¼" x 5" or larger, vertical mounting; 9T—7⅛" x 2⅝" x 5½" or larger, horizontal mounting; vertical mounting with approximately same volume available.
PRICE: 5T—$120.00 and up; 9T—$42.00 and up.

TAPPED DELAY LINES TYPE 6T 7T 8T

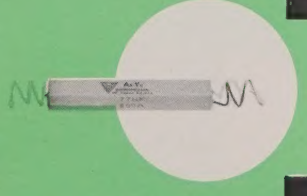


Specifications

NUMBER OF SECTIONS: 6T—10 sections; 7T—30 sections; 8T—20 sections of M-derived network.
RISE TIME IN PERCENTAGE OF TOTAL DELAY: 6T—15%; 7T—8%; 8T—10%.
INPUT VOLTAGE: 500 volts maximum for most types.
TEMPERATURE COEFFICIENT: Less than 0.005% per degree centigrade.
TOTAL TIME DELAY IN US: 0.1, 0.125, 0.2, 0.25, 0.3, 0.33, 0.4 up to 37.5 us.

CHARACTERISTIC IMPEDANCE IN OHMS: 50, 70, 75, 95, 100, 150, 200, 250, 300, 400, 500, 600, 750, 800, 1000, 1500, 2000, 2500 and 3000.
NUMBER OF TAPS: Horizontal mounting. 6T—11 taps; 7T—4 taps; 8T—6 taps. Vertical mounting, 2 taps; additional taps on request.
PHYSICAL SIZE: Horizontal mounting, 6T—6-1/16" x 15/16" x ⅞"; 7T—5⅝" x 2-11/16" x 15/16"; 8T—5⅝" x 15/16" x 1-13/16"; vertical mounting with approximately same volume available. **PRICE:** 6T—$22.00 and up; 7T—$40.00 and up; 8T—$30.00 and up.

MINIATURE DELAY LINES TYPE 3T 6C 7C



FEATURES • Physical Size; 3T1 series—⅝" x ⅝" x 4", 3T2 series—⅝" x ⅝" x 6"; 6C series—5/16" dia., approximately 5½" long; 7C series—½" x ½" square, 2½" to 3¾" long . . . Rise time approximately 8% of time delay for 3T1 series, 6% for 3T2 series, 10% for 6C-7C series.

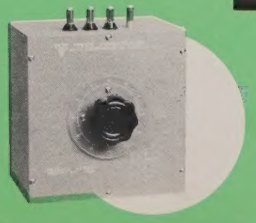
Specifications

CHARACTERISTIC IMPEDANCE IN OHMS: 75, 150, 200, 250, 320, 420, 500, 600, 750, 1000, 1200, 1500 up to 4000.

TIME DELAY IN US: 0.05, 0.082, 0.092, 0.112, 0.115, 0.132, 0.138, 0.14, 0.152, 0.17, 0.175, 0.18, 0.2, 0.5, 1, 2, up to 60 us.

FREQUENCY RESPONSE: 6C series—over 10 megacycles; 7C series—cutoff frequency equals 3/D, 3T1 series—4/D, 3T2 series—6/D, where D is the total time delay of the unit.
WEIGHT: Less than 6 ounces.
PRICE: 3T—$36.00 and up; 6C—$13.50 ea.; 7C—$24.00 ea. Quantity discounts.

STEP VARIABLE LINE TYPE 605 606



FEATURES • Time delay accuracy ±1% at any point . . . Temperature coefficient 0.005% per degree C . . . Can be used for matched low output impedance . . . Time delay per step 1/60 of the total time delay for Type 605, 1/120 for Type 606 and 607 . . . Rise time less than 6% for Type 605, 4% for Type 606, 3% for Type 607 . . . **PRICE:** $130.00 and up.

TYPE	605a	605a1	605b	605c	605c1	605c2	605d	605e	605f	605g	605h	605i	605i1	605i2	605i3	605j	605k	605l	605m
DELAY	.6 us	1.2 us	1.5 us	3 us	3 us	4.5 us	6 us	12 us	9 us	30 us	48 us	60 us	75 us	150 us	300 us	600 us	1200 us	2400 us	6000 us
Zo	75	75	95	190	50	75	300	760	150	1000	620	500	1000	500	500	1000	500	1000	500
TYPE	606a	606a1	606b	606c	606c1	606c2	606d	606e	606f	606g	606h	606i	606i1	606i2	606i3	606j	606k	606l	606m
													607i1	607i2	607i3	607j	607k	607l	607m
DELAY	1.2 us	2.4 us	3 us	6 us	6 us	9 us	12 us	24 us	18 us	60 us	96 us	120 us	150 us	300 us	600 us	1200 us	2400 us	4800 us	12000 us
Zo	75	75	95	190	50	75	300	760	150	1000	620	500	1000	500	500	1000	500	1000	500

PHASE METERS

405 Series—Direct reading in degrees, independent of signal amplitudes, 1 cps to 500 kc.

205A-B—0.05° or 1% accuracy, 100 kc to 1500 megacycles.

202 Vectorlyzer—1° full scale sensitivity, 0.005° deviation can be read.

524 Digital Phase Meter—0.1° accuracy, direct reading in four digits.

308A-B Transfer Function Analyzer—1 cps to 300 kilocycles, automatic plotting of Nyquist diagram.

208A Phase Generator—0.1 degree accuracy, 0 to 360 degrees.

DELAY LINES

Continuously Variable—505, 521, 551 and 801 Series, resolution time 8×10^{-11} sec.

Tapped—5T, 6T, 7T, 8T, 9T, 10T, 11T Series, time delay 0.1 us to 0.2 sec.

Precision Variable—605-6 and 611 Series, time delay 0 to 12,000 us.

Step Variable—602-3 Series, equal input and output impedance.

Miniature Fixed—6C, 7C Series, small physical size, 75 to 4000 ohms.

Special units to meet your requirements and Mil specifications.

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